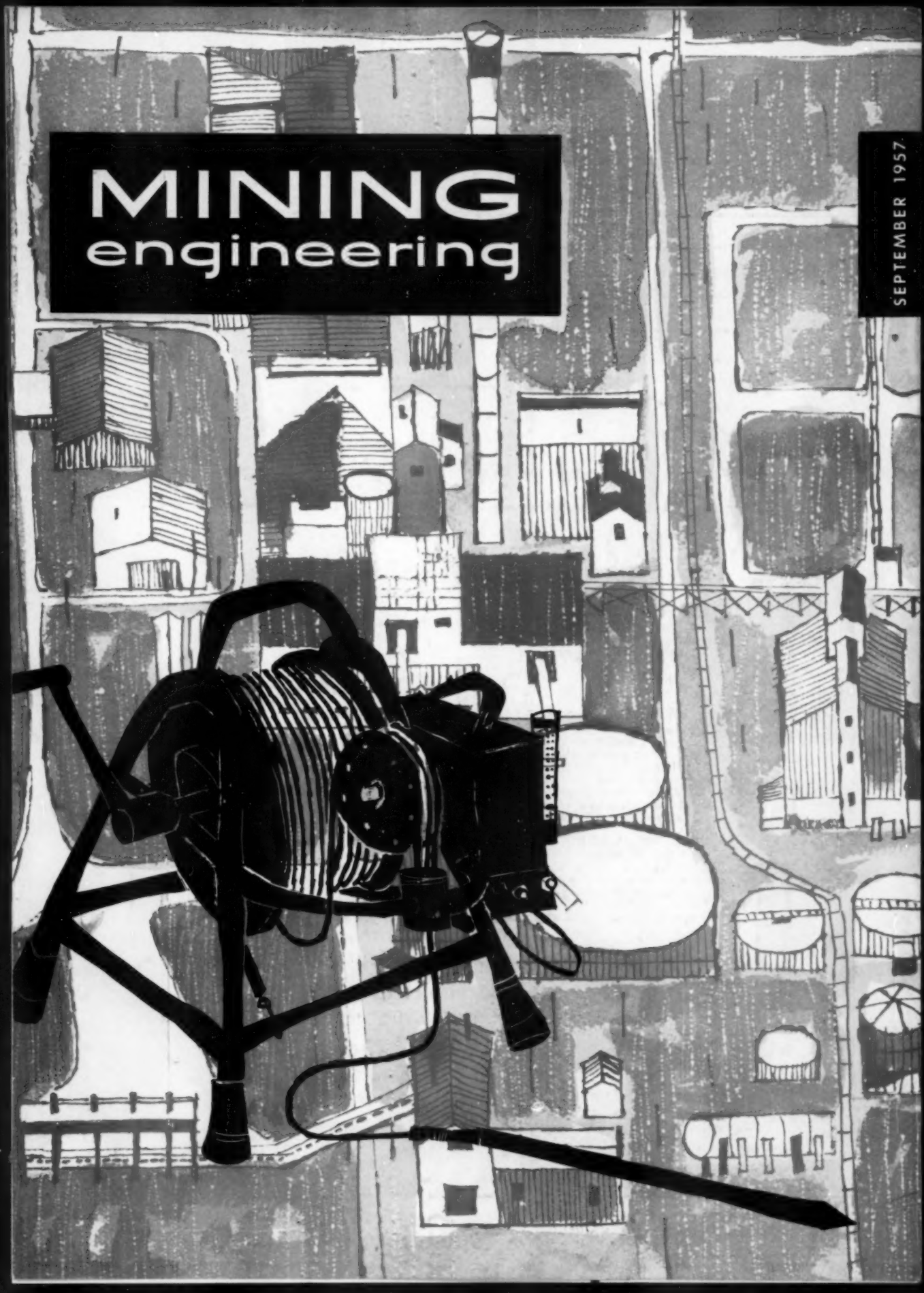
MINING
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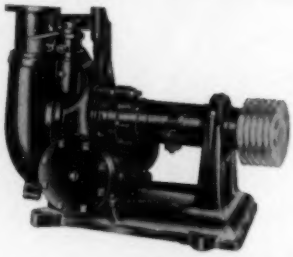
SEPTEMBER 1957

WILFLEY SAND PUMPS

LOW COST PUMPING



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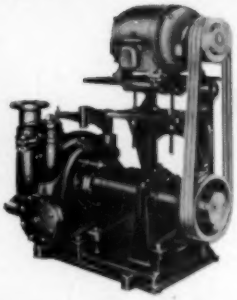

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ABC

MINING engineering

VOL. 9 NO. 9 SEPTEMBER 1957

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The probe symbolizes a continuing search for uranium extraction processes offering greater flexibility, higher recovery, or, most important, *lower* costs. Cover by Herb McClure.

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Junior Geologist, B.S., age 26. Veteran. Prefer foreign employment. M-347.

Mining Engineer, B.S., M.S. degrees mining engineering, age 31. Good scholastic record. Registered professional engineer. Married. Six years experience chiefly in coal preparation with some iron ore beneficiation work. Desires permanent responsible position in process development work in ore beneficiation, preferably in East or Midwest. Currently employed; available after reasonable notice. M-348.

Mineral Dresser, mining engineering background, B.A., B.S., E.M., M.S., age 35. Ten years experience, seven in mineral dressing research and three in instruction in mineral dressing and mining engineering. Research involved separations by flotation, gravity, magnetic, and shape; classification, fine particle size analyses, flocculation, surface properties of silicates. M-349.

Mining Engineer, B.S. in mining engineering, age 29. Two years experience underground, four years experience open pits. Includes underground mine engineer; open pit mine engineer; open pit reserve estimating, planning, and layout work. Married. Prefer West or foreign location. Desire responsible position with opportunity for advancement. M-350.

Mining and Geological Engineer, 31, married, graduate engineer, pilot's license. Four years experience open pit mining and underground. Two years with Army Engineering Research and Development Laboratories concerning steels and facings for heavy equipment cutting edges. Steam and diesel engineer's license. Desires position West or foreign. M-351.

Geologist, B.S., age 40. Four years experience minerals exploration and deposit evaluation. Drilling, strip mining, and milling. General and executive management. Government specialist in nonmetallic minerals. Location, immaterial. M-353.

Manager or General Superintendent, B.S. in metal mining 1926, age 51. Twenty years experience large metal mining companies, acquainted with underground, surface, and dredging methods. Can get results from native labor. Prefer West or foreign. M-352.

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Mining Engineer-Geologist, 40 to 65, degree in mining engineering, with minimum of ten years work in mining industry including minerals, exploration, mining development and improvement, and mine operations. Will act as consultant and advisor to foreign mining industry. Will explore and evaluate undeveloped resources and make recommendations for development, etc. Salary commensurate with past earnings and experience; transportation expenses and quarters allowance will be paid. Location, foreign; climate subtropical; family may accompany applicant. Duration, 12 to 15 months with possibility of extension. F4857.

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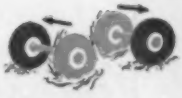

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Prospecting for Uranium and Other Related Deposits in New Jersey, by Kemble Widmer and Frank J. Markewicz, *State Dept. of Conservation and Economic Development,* Geology, 520 E. State St., Trenton 25, N. J., 10¢, 1957.—The pamphlet includes information on the discovery of monazite, thorium, and rare earth minerals which are of growing importance to industry. More emphasis has been placed on the prospecting criteria and the mineral associations as they apply to New Jersey. The booklet is a new and completely revised edition of an earlier pamphlet on the subject.

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Gasification of Pulverized Coal in Suspension, Research Bulletin No. 7, by C. G. von Fredersdorff, E. J. Pyrcioch, and E. S. Pettyjohn, Information Service, *Institute of Gas Technology,* Technology Center, Chicago 16, Ill., 71 pp., $5.00, 1957.—The Bulletin presents the results of work done by the Institute of Gas Technology on the gasification of pulverized coal in suspension with oxygen and steam. Particular emphasis is given to the performance and life of the gasifier refractories under slagging conditions, and the utility of the ash-collecting arrangement.

Canadian Mines Handbook 1957, compiled, printed, and published by *Northern Miner Press Ltd.*, 116 Richmond St. W., Toronto 1, Canada, $3.00, 324 pp., 1957.—An up-to-date edition of the well known reference, part I lists principal companies including inactive and extinct companies; Part II, metal mines classified and mining stock prices. This year the handbook includes 12 maps of the principal Canadian mining districts prepared by Langridge Ltd.

Year Book of the American Bureau of Metal Statistics, 36th annual issue for year 1956, *American Bureau of Metal Statistics,* 50 Broadway, New York 4, N. Y., 133 pp., $3.00 postpaid in U. S. and Canada, $3.25 to other countries, 1957.—This annual publication covers, from a statistical basis, the economy of nonferrous metals on a world-wide scale. Major nonferrous metals covered are copper, lead, zinc, aluminum, gold and silver, tin, antimony, cadmium, magnesium, cobalt, nickel, molybdenum, and platinum. Some of the pertinent data included in this volume cover statistics of production, consumption, operations, imports and exports of the U. S. and the United Kingdom, metallurgical plants and capacities, and other economic information.

The Demand and Supply of Scientific Personnel, by David M. Blank and George J. Stigler, *National Bureau of Economic Research,* 261 Madison Ave., New York 16, N. Y., 198 pp., $4.00, 1957.—Drs. Blank and Stigler have investigated ways to explain and eventually to predict the demand and supply of technological and professional workers, under a grant to the National Bureau of Economic Research by the National Science Foundation. In numerous areas the information necessary to reach precise conclusions is incomplete, and their report provides a valuable guide to types of economic information needed for fuller and deeper understanding of the technological professions.

Some Occurrences of Uranium and Thorium in Montana, by Leonard D. Jarrard, *The Montana Bureau of Mines and Geology,* Room 203-B, Main Hall, Montana School of Mines and Geology, Butte, Mont., 90 pp., $1.00, 1957.—The booklet is designed to aid the uranium and thorium prospectors of Montana by pointing out the characteristics and occurrence of different types of radioactive deposits. Methods of prospecting for radioactive materials are discussed, and sources of aid to prospectors are given.

AIME announces that *The Porphyry Coppers in 1956* by A. B. Parsons is now available. For detailed content, ordering, and cost information, see p. 1030 of this issue.

Handbook of Powered Industrial Trucks, published by the *Industrial Truck Asscoiation,* Suite 526-28 Washington Loan and Trust Bldg., Ninth and F Sts., Washington 4, D. C., 94 pp., $5.00, 1957.—The first manual to cover all types of powered industrial trucks, this is the result of more than two years of combined effort by various Association committees. Of particular interest is a 20-pp. section devoted to engineering data, stated to be the most complete compendium of technical information on industrial trucks ever published.

The Proceedings of the Cleaner Air for Urban Areas Symposium, Information Services, *Franklin Institute Laboratories,* 20th and Parkway, Philadelphia 3, Pa., 69 pp., $3.00, 1957.—The volume contains transcripts of speeches presented at the Franklin Institute on the scientific approach to the problem of air pollution control and its effect in the growing community.

Coal As a Raw Material, published by *The Royal Institute of Chemistry,* 30 Russell Square, London, W. C. 1, England, price 4s., 1957.—The book covers the future and importance of coal in the industry and science.

Statistical Abstract of the United States, by the *United States Dept. of Commerce,* Washington 25, D. C., more than 1000 pp., $3.75, 1957.—The volume is a useful tool for the serious researcher into population changes, business trends, foreign trade, agricultural production, or any of the hundreds of subjects indexed, in its 34 chapters.

Directory of Consulting Engineers and Architects, published by the *San Francisco Chamber of Commerce,* Industrial Dept., 333 Pine St., San Francisco 4, Calif., 24 pp., $1.00, 1957.—Firm names, principals, bank references, educational and professional qualifications, nature and scope of services, and principal accomplishments of 72 engineering firms and 45 architectural firms are included in the directory.

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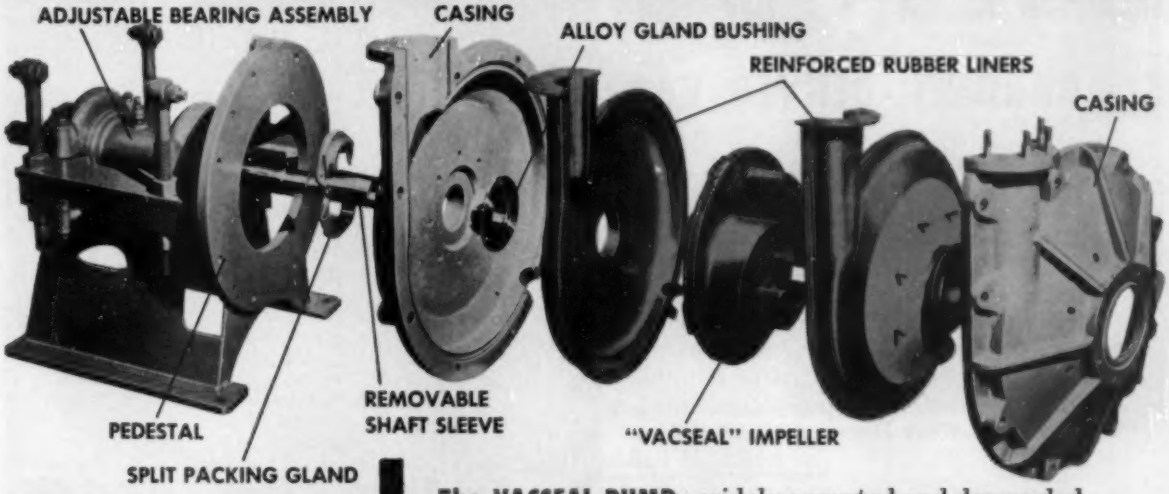

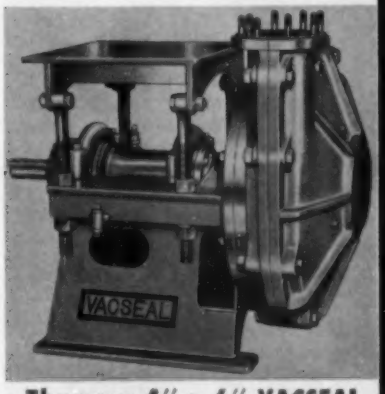

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Weight: (With Tappet Chuck) lb.	94	97	100	103	80¼	82¼	84¼	86¼	90	91	94
Weight: (With Collared Chuck) lb.	89¾	92¾	95¾	98¾	76	78	80	82	85¾	86¾	89¾
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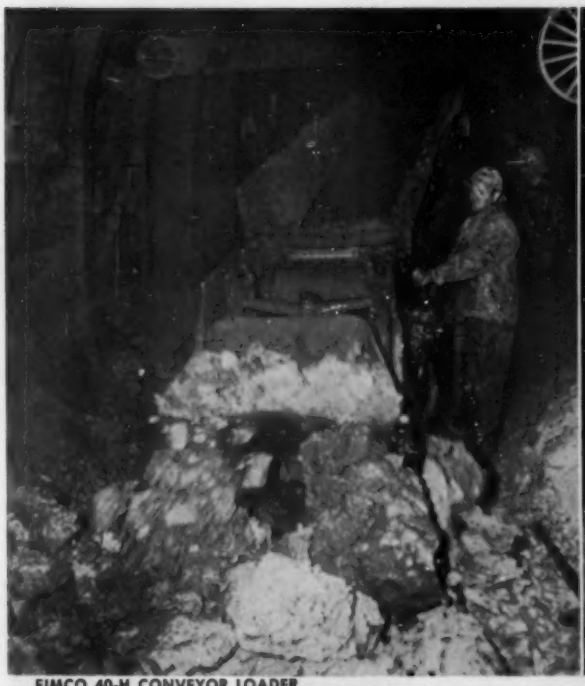

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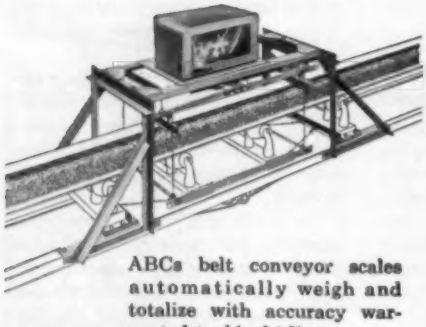

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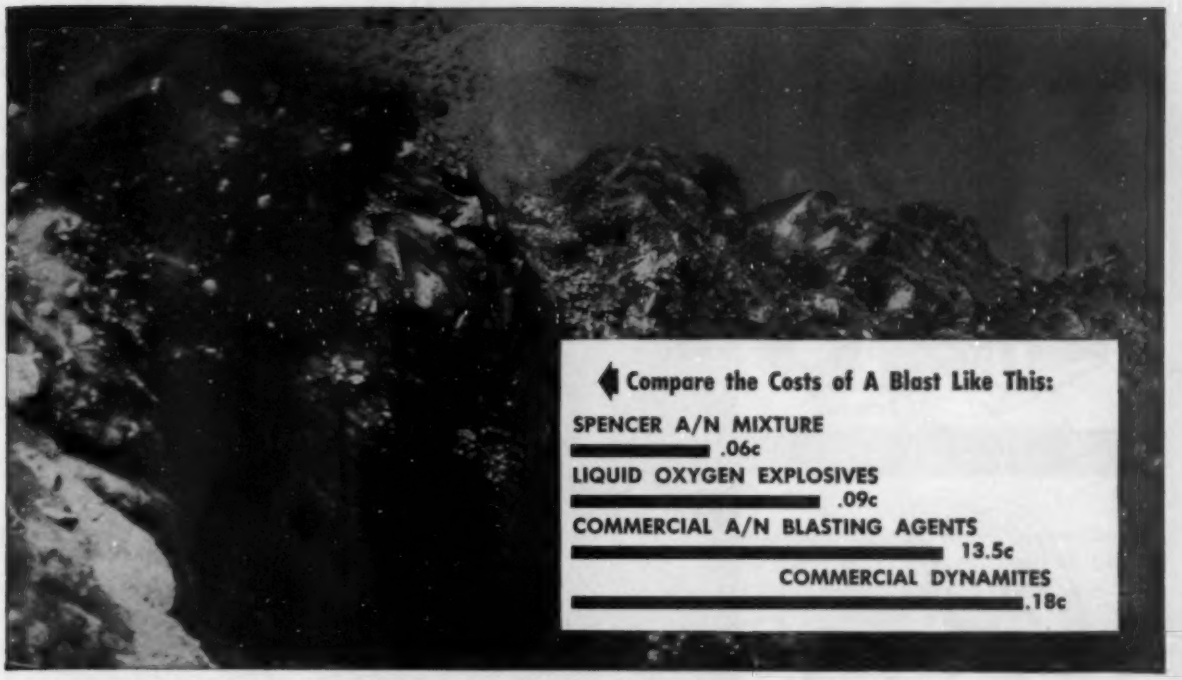

YOU CAN CUT BLASTING COSTS UP TO 50% with new ammonium nitrate blasting process pioneered by Spencer Chemical Company and Maumee Collieries.

Let Spencer Chemical Company Show You

How To Get Better Results With New Ammonium Nitrate Blasting Process

Maximum benefits from new blasting method demands knowledge of nitrate types, packing, detonation, etc. Pioneer supplier of ammonium nitrate for blasting, Spencer offers you free technical advice and service.

The startling announcement of a revolutionary new, low-cost blasting method was made about two years ago. The technique, developed by Maumee Collieries using Spencer Prilled Ammonium Nitrate, cut blasting costs up to 50%. Also, improved fragmentation made this method about 25% more efficient.

The importance of this new method to you has now been affirmed by practically all major dealers in explosives. But almost each month new data reveals improved techniques by which even greater savings can be made.

Continuing our pioneer work begun with Maumee Collieries—Spencer has since made intensive tests using ammonium nitrate for open-cut blasting for coal, iron, and rock. In fact, Spencer Chemical Company is prepared to offer you the latest and most complete available data about almost every open-cut blasting situation in this hemisphere.

To get the full benefits of this accumulated knowledge and experience, consult Spencer Chemical Company when you are ready to find out for yourself about this wonderful new blasting process. Spencer's special bulletin, "Cut Blasting Costs With Spencer Prilled Ammonium Nitrate," and the most expert technical advice in the country are yours for the asking. Mail the coupon—today!

MAIL THIS COUPON:

Spencer Chemical Company
Sales Supervisor,
Industrial Ammonium Nitrate
404 Dwight Building
Kansas City 5, Missouri

☐ Please send me free Spencer bulletin, "Cut Your Blasting Costs with Spencer Prilled Ammonium Nitrate."

☐ Please have a Spencer Technical Service Representative call—without cost or obligation to me.

Name_____

Company_____

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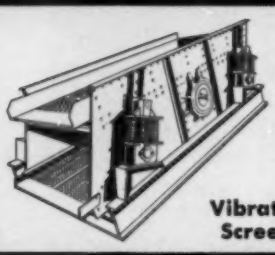
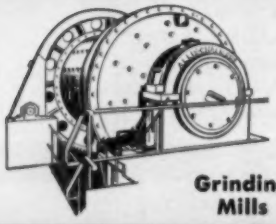
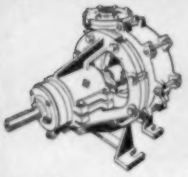
HERE'S YOUR One Source...



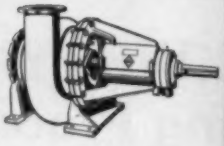
Vibrating Screens



Grinding Mills



Rubber-Lined Pumps



Solids Handling Pumps

Send for Bulletin 07R7995

"Work index" formula enables you to evaluate crushing and grinding operations . . . compare efficiency of plants, circuits, machines. This handy reference offers only scientific method of determining the right machine and required horsepower.

Gyratory Crushers

Emergency unloading, wear compensation, setting changer are flip-of-the-switch operations on Allis-Chalmers crushers equipped with *Hydroset* mechanism. Even the world's largest crusher utilizes the convenience and economy of the *Hydroset* mechanism.

Texrope Drives

For maximum efficiency in transmitting power between motor and machine, Allis-Chalmers offers a complete line of *Texrope* V-belt drive equipment . . . variable speed sheaves, fast adjusting motor bases, *Texrope* belts with 33% more gripping strength.

GET ALL THE FACTS. See your Allis-Chalmers representative or write Allis-Chalmers, Milwaukee 1, Wisconsin.

ALLIS-

One Responsibility

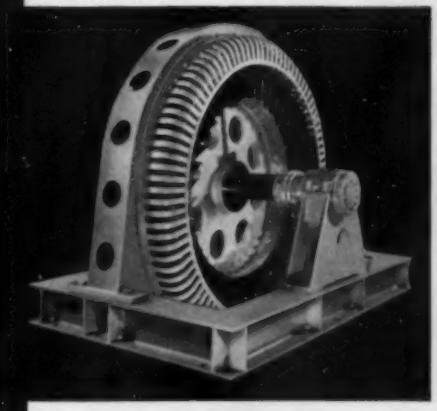
PROFIT PACKAGE

Processing Machinery, Pumps, Motors and Power Equipment Engineered to Work Together . . . Designed to HELP YOU Increase Production and Cut Costs

CRUSHERS, grinding mills, screens, pumps, generators, switchgear, transformers, motors, drives, control — *Allis-Chalmers builds them all.* And out of this unequalled diversity has come the unique ability to "coordineer" machinery and equipment for a complete process—yes, even for an entire plant.

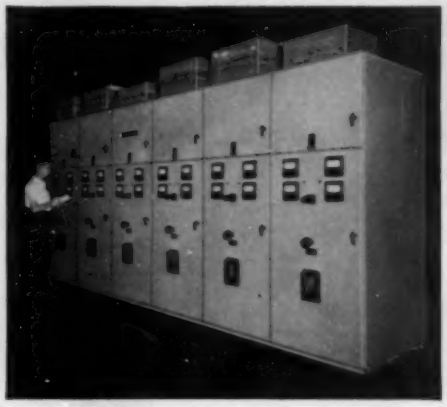
How it Works

Allis-Chalmers maintains separate departments staffed by research, design, manufacturing and application specialists for each product. "Coordineering" results from an interdepartmental exchange of ideas and technical information correlated in *one department specializing in mining applications.* In this department components are matched to meet the requirements of your job. New as well as existing equipment in your plant is integrated into a smooth, productive, profitable operation. And, of course, Allis-Chalmers assumes undivided responsibility for efficient performance.



Motors

Allis-Chalmers builds a complete line of motors from ½ horsepower and up. Applying the "work index" formula, Allis-Chalmers engineers can help you determine the required power input and apply the right size motor needed for maximum efficiency and economy.



Control

Starter illustrated features circuit designed to cut crusher downtime. Overload protection is provided by two sets of thermal overload relays. One set operates on slight overload to sound warning. Second set stops motor when temperature reaches the danger point.

Unit Substations

Designed for maximum flexibility. Additions or replacements to basic centralized unit can be made conveniently at any time. Strategically located, unit substations bring high voltages near load centers — cut cable costs, minimize line loss, save space, provide complete protection.

CHALMERS

A-C ALLIS-CHALMERS

Hydroset and Texrope are Allis-Chalmers trademarks.

A-5406

The only REVERSIBLE cap and adapter made...

Try this on- for SAVINGS!

Service-proved WEARPACT Cap Type Tooth —with foolproof retainer—cuts digging costs to record lows . . . even in taconite!

Probably by now you've heard of Wearpact Steel—the alloy with a combination of hardness and toughness not available in any other commonly used alloy.

Here's a new tooth and adapter design* cast in longer-wearing Wearpact . . . the ASF Cap Type Tooth and adapter —the *only* such tooth and adapter that's reversible for longer life. Note that the tooth itself is self-sharpening. Keeps on *slicing* through the ore and overburden—and when finally worn, there's less metal to throw away. *The tooth locks securely to the adapter.* No ASF retainer has ever failed in service.

As for service life, the cost-per-ton figures in large mines speak for themselves. Lowest of any tooth on record! Give this dollar-saving tooth a try! Write today to arrange for an installation.

Cut your costs with WEARPACT

CAST ALLOY STEEL

A PRODUCT OF

AMERICAN STEEL FOUNDRIES

3750 Canal St., Indiana Harbor, Indiana

*Patent Pending.

reduce drift support costs...

with CF&I ROCK BOLTS and REALOCK FABRIC

When you use CF&I Rock Bolts and Realock Fabric for drift support, you know you're using a method that:

- **Is fully tested for safety.**
- **Offers proved savings over older methods (35% less than timber square sets and 30% less than wedge-type bolts and landing mats, according to tests conducted by one of America's most progressive mining companies).**

Why does the combination of CF&I Rock Bolts and Realock Fabric afford such economy? First, the method is much faster and more versatile than older ones. And miners are able to do their own rock bolting with the same machines used to drive the heading. This is possible because CF&I supplies ¾" high-strength rock bolts and Pattin Type D-1 expansion shell rock bolts with left-hand threads to allow tightening by the left-hand rotation of drilling machines.

Get the complete story on how you can use the safe, economical bolt and fabric method of drift support in your own operations. Write today for complete details.

Note: CF&I Rock Bolts of the slot-and-wedge type are also available.

A twenty-minute color movie on Rock Bolting entitled "Make Mine Safety" is available for showing upon request through any of the district offices listed below.

THE COLORADO FUEL AND IRON CORPORATION

Albuquerque · Amarillo · Billings · Boise · Butte · Casper · Chicago · Denver · El Paso · Ft. Worth · Grand Junction · Houston
Kansas City · Lincoln (Neb.) · Los Angeles · New Orleans · Oklahoma City · Oakland · Phoenix · Portland · Pueblo · Salt Lake City
San Antonio · San Francisco · San Leandro · Seattle · Spokane · Wichita
CANADIAN REPRESENTATIVES AT: Calgary · Edmonton · Vancouver · Winnipeg

4601

"100% SATISFIED" with his GOLD MINE'S CAT* POWER

Up in the hills north of Trona, Calif., near the legendary "lost" Peg Leg mine, are the gold mine and mill of Argus Development Company. Two Caterpillar Electric Sets and a Caterpillar Engine supply all power for them. According to Russell A. Donnelly, Argus' president, "We're 100% satisfied with these units. We like their easy starting in cold weather, and their economy, dependability and quick pickup in power."

A Caterpillar D13000 Electric Set furnishes power for crushers, conveyors and lights at the mill, which has a capacity of 100 tons of ore per eight-hour shift. Another Cat Electric Set powers the hoist at the mine. There is also a Caterpillar Engine, veteran of more than 7000 hours, in a Gardner-Denver compressor. Ore is trucked 8½ miles from the mine to the mill.

Excellent as these units are, the new Cat Electric Sets are even better. They are self-regulated sets, giving precise control of voltages from no-load to full load, and simplified operation without adjustments. The new Caterpillar Electric Sets produce greater power from more compact units . . . for easy installation or change of location. They are available in a complete range of sizes up to 350 KW for permanent installations or as portable power plants.

Find out for yourself why Russell Donnelly says, "We bought Caterpillar because it's tried and proven. We like the performance and the dealer service." Call your Caterpillar Dealer today for full information on the electric set that best suits your needs. And count on your dealer for fast, skilled service and parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

MODERN HEAVY-DUTY ELECTRIC SETS

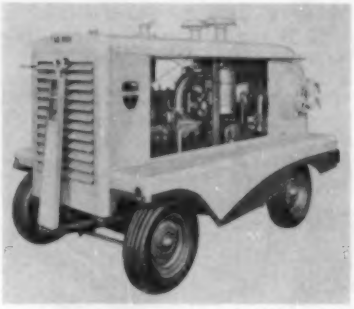
Manufacturers News

News
Equipment
Catalogs

• FILL OUT THE CARD FOR MORE INFORMATION •

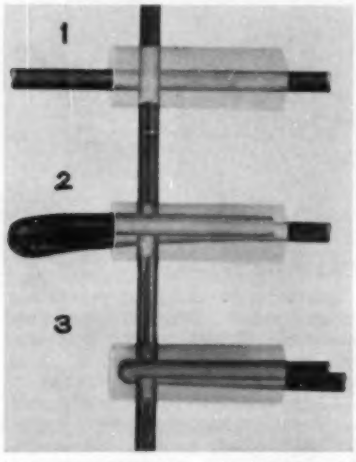
Rotary Air Compressor

The 600RD2 is the first of a new line of compressors by *Le Roi Div.*, Westinghouse Air Brake Co. Portable 600 cfm unit weighs 7730 lb and is powered by a GM-71 diesel. Overall height is 7 ft 6 in.; length is 12 ft 6 in.; width is 6 ft 8 in. **Circle No. 1.**



Fuse Connector

Detonating fuse from shot hole and trunk lines is quickly and surely coupled with a plastic connector by *Austin Powder Co.* which eliminates knot tying. Shot hole fuse is first pushed through the length of the connector. Trunk line is then pressed



into grooved slots. Finally, branch line is passed over trunk line, returned the length of the connector and pulled tight. **Circle No. 2.**

Motor Scraper

Allis-Chalmers has added the Model TS-160 with 12-ton payload to its line of motor scrapers. Double acting bowl lift jacks exert down pressure at cutting edge for fast penetration. Rated at 155 hp, the scraper has five forward speeds from 3.1 to 25.4 mph, and reverse at 3.1 mph. Capacity is 7 cu yd struck, 9.5 cu yd heaped. **Circle No. 3.**

Big Separator

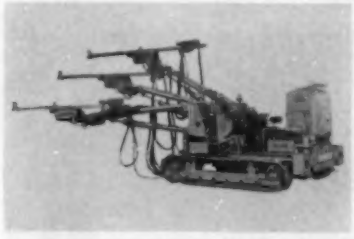
Feed rates from 8000 to 32,000 lb per hr can be handled by a new 16-rotor high intensity magnetic separator, the largest yet produced by *Carpco Mfg. Inc.* Each rotor unit operates individually. Together the rotors give any combination of flow of material. **Circle No. 4.**

Stoper

A new stoper with direct or telescopic aluminum feed legs is announced by *Gardner-Denver Co.* Designated the Model R68, the stoper features automatic water control. It is available with push-button or rotary-type feed controls, and either collared or tappet chuck. Steel changes range 18 to 36 in. **Circle No. 5.**

Mobiljumbo

Push-button rock drilling takes another forward step with the introduction of *Gardner-Denver's* new



JMT Mobiljumbo. Available with crawlers powered by diesel-hydraulic drive or by 5-cyl radial air motors, the unit is furnished with two or three hydraulic booms. Three flood lights get power from an air-motor-driven generator. **Circle No. 6.**

Channel-Flo

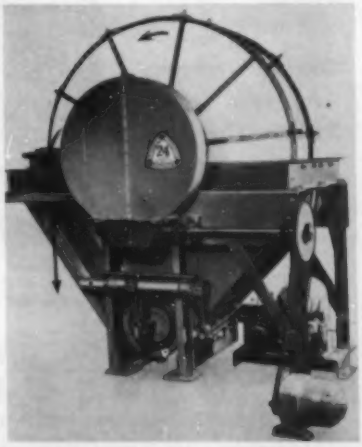
A two-stage, 200 psi rated air compressor is now available from *Ingersoll-Rand Co.* in 1.5 and 2-hp sizes. A complete Channel-Flo unit includes motorcompressor, cushioned rubber mounting on an ASME vertical tank, piping and fittings, and an automatic start-stop control. Designed for safety and space saving, the compressor may be mounted suspended or on ceiling, wall, or shelf. Air receiver can be put in an out-of-way space. **Circle No. 7.**

Extensible Platforms

Mobile Aerial Towers Inc. has introduced three series of Hi-Rangers to eliminate the need for ladder, rope, or scaffold setups in such operations as roof scaling, drilling, and charge setting. Maximum reaches range 24 to 100 ft—lifting capacities 500 to 2000 lb. Worker can elevate or lower platform by working a single control lever on the personnel basket. **Circle No. 8.**

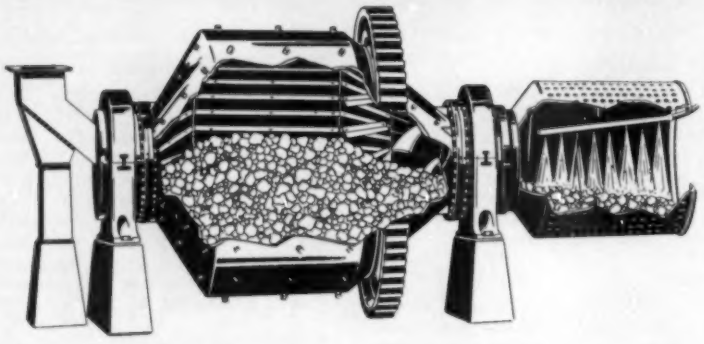
Agitator Filter Mechanism

Pulp agitation for increased filter capacity is supplied by a pulsating unit located below the discs of a new filter by *Denver Eqpt. Co.* Agitation speed is adjustable to maintain a homogeneous pulp regardless of its nature. Elimination of packing gland, sealing water, and bearings



in the tank makes maintenance problems small. The agitator feature is available on all sizes of Denver disc filters. **Circle No. 9.**

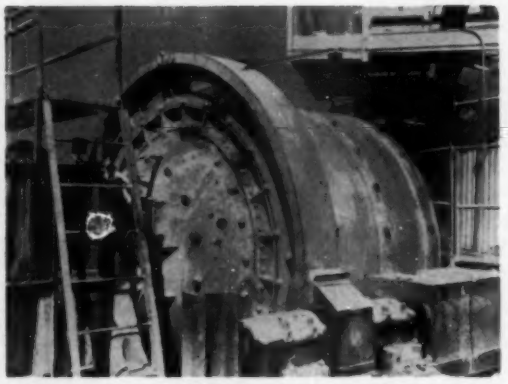
HARDINGE SCRUBBERS FOR PIT-RUN MATERIALS



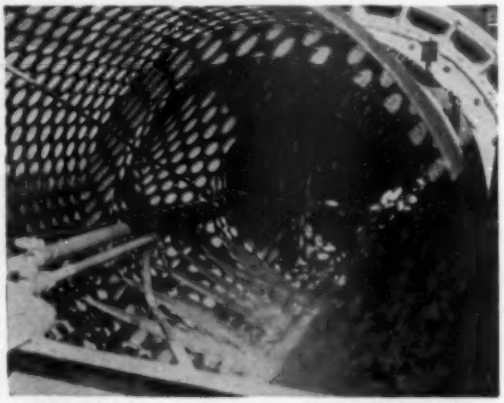
Large diameter, short length trunnions permit chute feeding of unsized ore and rock at rates up to 600 tons per hour.

The mass loading and ball-mill action in the scrubber quickly and completely slurries the clay and dirt, permitting ready separation on washing screens or trommels.

Complete specifications upon request. Bulletin 37-B-2.



Crushed dolomite presents a difficult cleaning problem. The Hardinge 10' x 66" scrubber above is doing the job satisfactorily in a California dolomite plant.



Scrubbed stone emerging from a Hardinge Scrubber into a washing trommel which rotates with the Scrubber.

HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works

New York • Toronto • Chicago • Hibbing • Houston • Salt Lake City • San Francisco

Core Bits

Metal Carbides Corp. will fabricate their Superset core bits from diamonds supplied by customers, setting them by hand in a tungsten carbide crown brazed to a standard threaded blank. Resulting savings are claimed high. Metal Carbides will also supply complete bits or salvage stones from used bits. **Circle No. 10.**

Lightweight Block

Sauerman Bros. Inc. has added a heavy duty rigger-slusher block to their Durolite line. Claimed highly shatter resistant, the block will withstand 14-ton loads without damage. Designed for quick opening, it features a wide flange for use of wire rope up to ¾-in. diam. Roller bearings are sealed. Block weighs 44 lb. sheave is 10-in. diam, and overall length is 23 in. with swivel hook. **Circle No. 11.**

Pilot Plant Separator

Laboratories and pilot plants are recommended users of the new Model HP167 high tension separator by *Carpco Mfg. Inc.* Feed, at rates up to 300 lb per hr, is separated by a beam type electrode—a compact airlift recirculates loads. Unit has 6-in. rotor which turns at 10 to 800 rpm. Tailing and concentrate splitter blades can be preset, and electrode space changing is possible during operation. Overall dimensions of the separator, 7x3x2 ft. **Circle No. 12.**

News & Notes

Mine & Smelter Supply Co. and its subsidiary *Colorado Iron Works Co.* recently completed a $1 million expansion program which includes a new office building and an expanded plant. Facilities will permit increased production of Wilfley tables, Massco-Grigsby pinch valves, and laboratory equipment.

(21) MINE TRACK DEVICES: *American Mine Door Co.* offers a new catalog of Canton automatic track devices with diagrams of typical installations. Both electric and air-operated switch throwers and contactors are detailed. New Model E contactor, when coupled with the Aero-Throw switch thrower, allows full air operation without use of a control panel.

(22) HIGH POWER ENGINES: A 16-page bulletin from *Nordberg Mfg. Co.* fully describes a line of four-cycle in-line engines ranging in horsepower from 640 to 2150. The diesel, Duafuel, or spark ignition gas engines provide compact power for generators, dredges, pump stations, and other applications. Bulletin 257 supplies data sheets on power ratings, outline drawings, and all dimensions needed for preliminary planning. Supercharged, supercharged and intercooled, and Supairthermal units are available.

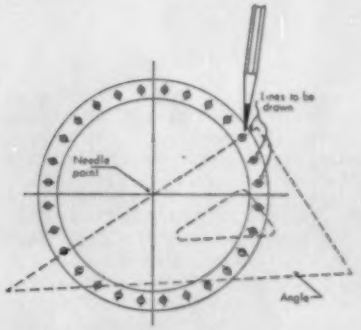
(23) DRILLING HOLES: A hefty catalog covering working data in drilling for minerals, oil, gas, and water is available from *Stardrill-Keystone Co.* Included in the 164-page publication is information on reverse circulation, hydraulic bit dressing equipment, tempering, and necessary data on six basic methods of drilling. All significant figures are accompanied by their metric equivalents.

(24) EXPLOSIVES PRODUCTS: Users of explosives will find helpful facts and figures, and a full line of products in a new edition of a 48-page catalog by *Atlas Powder Co.* Materials and methods are detailed in a general section, and more than 150 items are listed in the catalog portion. Properties and applications are included of 18 types of high explosives, six low order blasting agents, blasting caps, blasting machines, safety fuse, and accessories. The booklet, entitled "Atlas Explosives Products," is illustrated.

Free Literature

(25) WIRE SCREEN: Two stainless steel heavy duty screens have been added to the Kleenslot line by *Wedge-Wire Corp.* Models G187 and GB187 have standard spacing of .010 in. and larger.

(26) DRAFTING TIPS: Fifty-nine shortcuts for quick drafting and computation work are set down with illustrations in a handy booklet



from *Frederick Post Co.* New approaches to old problems make "Time Saving Tips for the Draftsman and Engineer" convenient without sacrificing precision.

(27) 1956 FLOTATION INDEX: "The 27th Annual Addition to the Flotation Index" is now available from *Dow Chemical Co.* A bibliography of articles appearing in leading mining publications of the world, the index includes those concerned with flotation research, general mineral dressing, heavy-media separation, and milling operations. The new booklet covers information published in 1956.

(28) CHEMICAL FEEDER: *Clarkson Co.* announces a new bulletin, No. 575. Featured is the Clarkson feeder Model E in 18-8 stainless steel for economical, controlled feeding of reagents. Feeder frame is cast aluminum.

(29) GEOLOGICAL INVESTIGATION: *The Ontario Department of Mines* offers a geological circular with details on the Mississippi quartzite of the Blind River area. Three maps are included in the 31-page publication which gives the results of a 1956 investigation of various sedimentary structures in this uranium-rich section of Canada.

(30) CORROSION PROOFING: Choosing corrosion proofing methods and products, determining comparative resistance of various cement mortars, and calculating quantities needed, are discussed in a new edition of the *Pennsalt Chemicals Corp.* corrosion proofing brochure. Eight pages of data give information on a line of corrosion proofing cement mortars, interliners, protective coatings and linings. Installations surveyed include linings in acid concentrators, stacks, pickling tanks, as well as sumps, pits, and trenches for handling industrial wastes.

(31) HARD SURFACING: Depositing tungsten carbides on steel, cast iron, or copper alloys without fusion is possible with the Dril-Tec 86, 88, and 89 rods, according to *Eutectic Welding Alloys Corp.* Materials provide cutting or abrasion surfaces on equipment used for drilling and earth removing such as coring tools and bucket teeth.

(32) SEPARATION PLANTS: A technical bulletin describing factory built heavy media separation plants for coal, ore, and rock products beneficiation is available from *Southwestern Engineering Co.* Bulletin E56-1R includes basic application data and a chart on the density relations for magnetic separation media.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

9

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Dec. 15, 1957—if mailed in U. S. or Canada

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

Name_____ Title_____

Company_____

Street_____

City and Zone_____ State_____

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
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51	52	53	54	55	56	57	58	59	60
61	62	63	64	Students should write direct to manufacturer.					

(33) MOTOR STARTERS & CONTACTORS: A complete line of starters and contactors is described in a new 12-page bulletin from *Allis-Chalmers Mfg. Co.* These units have been applied to such drives as pumps, crushers, blowers, fans, and screens.

(34) TORQUE CONVERTERS: Four-page data sheet 101 from *National Supply Co.* explains features of National torque converters for excavators, cranes, and shovels. Types and makes of engines with which the 17 available sizes can be used are listed. Range is 100 to 1000 hp.

(35) APRON FEEDERS: A redesigned line of stationary and portable apron feeders has specifications listed in Form 662 from *Pioneer Engineering.* Basic units can be furnished in one of four standard widths, five standard lengths, and one of three types of drives.

(36) ROTARY DRILL: Two bulletins from *Davey Compressor Co.* outline features of the Model M-8TA tractor-mounted rotary drill. Unit has rated capacities to 2000 ft.

(37) AIR ENGINEERING: A bulletin from *Aerovent Fan Co. Inc.* covers propeller fans—specifications, construction, maintenance, and installation. For special conditions a section is included on special shapes, coatings and motors, corrosion resistance and temperature guides.

(38) PRODUCTS & SERVICES: *Denver Eqpt. Co.* has an 8-page bulletin detailing latest improved models of equipment for the mining, milling, and chemical processing industries. Machines are illustrated with brief, charted specifications. Testing, engineering, and mill design services are also covered.

(39) BIT COUPLINGS: *Brunner & Lay Inc.* offers a line of bit couplings and adapters, among other blast hole drilling accessories.

(40) SUMP PUMP: Model VP-8 is a pneumatic sump pump by *Gardner-Denver Co.* handling heads up to 280 ft with a capacity of 250 gpm. Pump will not bury itself in mud and has several advantages added to those of the smaller Model VP-4. These include: direct air flow through pump motor to reduce friction; uniform-size bearings; easily installed, economical packing seal; 0 ring leakage seals. Also all bearings of the 110-lb unit run in oil.

(41) CABLE SPLICING: *Okonite Co.* offers a bulletin on a weather resistant, self-fusing splicing tape for rubber and plastic cables. Okoweld tape may be used on cables carrying up to 2000 v without using other materials.

(42) CABLE CLAMPS: Application without disassembly is the major feature of the 480 Series power cable clamps by *Aluminum Co. of America.* Aluminum halves are joined by anodized bolts without nuts. Three sizes cover a wide range of cable diameters.

(43) STRIPPING METHODS: Current information on drilling, blasting, and excavating methods used in coal stripping is outlined in a new bulletin by the Explosives Dept. of *American Cyanamid Co.* Bulletin, entitled "Stripping Case Histories," unfolds into a 2-page chart which gives 46 case studies in condensed form for quick reference. Information is included on geological formations, excavating practices, drilling equipment, bit performance, drill patterns, blasting agents, and explosives ratios.

(44) DIAMOND CORE BITS: New Drillco diamond set core bits are furnished in DCDMA standard sizes from EXT to 7¾-in. diam. *Diamond Products Inc.* will supply West African stones of all qualities in a choice of three types of powdered metal matrices: standard, hard, superhard.

(45) CLAM SHELL BUCKETS: Quick action clamshells with cutting teeth and lip forged of T-1 steel are available from *Hutton Fabricating Mfg. Corp.* Reeving is block and tackle type and buckets are of all welded construction. Components are interchangeable in five different sizes.

(46) WELDING & CUTTING: *Linde Co.*, Union Carbide Corp. division, has an improved model of the Prest-O-Lite No. 420 outfit which can weld plate up to ⅜ in. and cut to 2-in. Changes in components and their positions make for easier use.

(47) CRANES & SHOVELS: A new 24-page catalog from *Gar Wood Industries Inc.* features a series of ¾-yd power excavators. The Model 75-B offers eight crawler options, gasoline or diesel engines, and a large selection of front end attachments.

(48) CUTTING AND DRILLING TOOLS: Catalog M-8 from the Mining Tool Div., *Kennametal Inc.* details a line of tungsten carbide cutter, rotary drill, roof, open pit, rock, and core and drag bits. Also described are pinning rods, augers, drive sockets, and adapters. A price book of Kennametal tools is included.

(49) PLASTIC PIPE: A 12-page catalog describing regular and high impact corrosion resistant rigid polyvinyl chloride pipe is offered by *Alpha Plastics Inc.* Tables are included on specific applications and necessary installation data.

(50) COAL PREPARATION: A new booklet from *Link-Belt Co.* features latest coal industry equipment and new preparation plants. Equipment section includes: unloading and handling facilities; cleaning, classifying, and conveying methods; crushing, blending, thermal drying; water clarification; loading and replacement units. Also described are a dual-bed air pulsated wash box, new tank-type heavy media vessels, car dumpers, and related equipment. Book 2655 has 36 pages of information.

(51) ELECTRIC SETS: *Caterpillar Tractor Co.* has announced three new portable diesel electric sets equipped with the new, compact Cat generator. The D311 develops 30 kw of 60-cycle, three-phase current, while the D315 is rated at 40 kw, and the D318 at 60 kw. Available with running gear or skid-mounted, the units are started and controlled from their instrument panels.

(52) STOPER: A loose-leaf data sheet on the Model S-12V Vac-Nu-Matic stoper is available from *Le Roi Div.*, Westinghouse Air Brake Co. For efficient dust collection, a DK288 high vacuum unit may be used with the stoper.

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Here's MORE efficient driver speed for HEAVY Loads

ALLIS-CHALMERS TEFC Wound-Rotor MOTORS

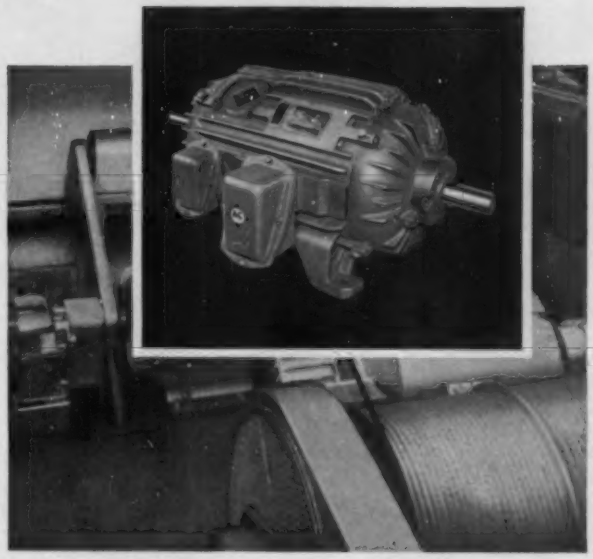
Where high inertia loads must be accelerated quickly and smoothly — yet power supply is limited — the Allis-Chalmers wound-rotor motor proves its efficiency . . .

High starting torque with this motor requires relatively low line-current. In addition, adjustable acceleration and running speed are possible through use of simple controls.

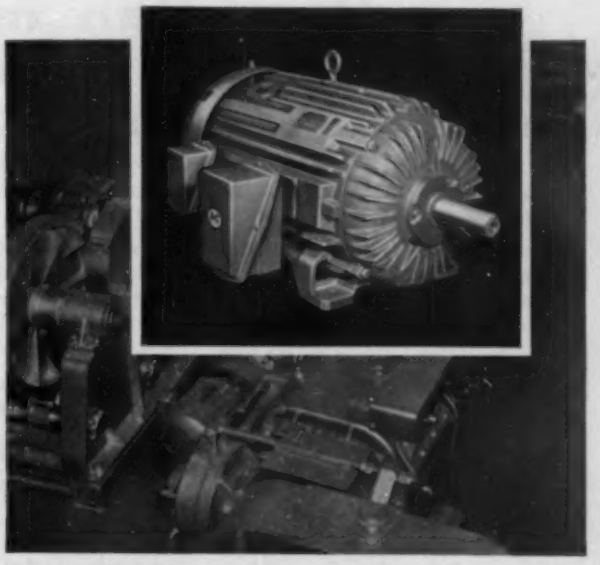
Other features of the TEFC wound-rotor motor include:

1. **Rib construction** provides ample cooling surface.
2. **Single enclosure** surrounds stator, rotor, slip rings, brushes and brush rigging. Gives maximum protection in moist, dirty, corrosive or hazardous atmosphere.
3. **Cast-iron frame** contributes rigid, distortion-free bearing support and keeps alignment true.
4. **Easy access** to collector rings and brushes permits on-the-spot inspection of brushes and commutators.

If you use hoists, lifts, cranes, conveyors, crushers or mills, find out more about the "MORE" in Allis-Chalmers wound-rotor motors. A-C motors also are available in various open types. Contact your nearby A-C sales office, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.



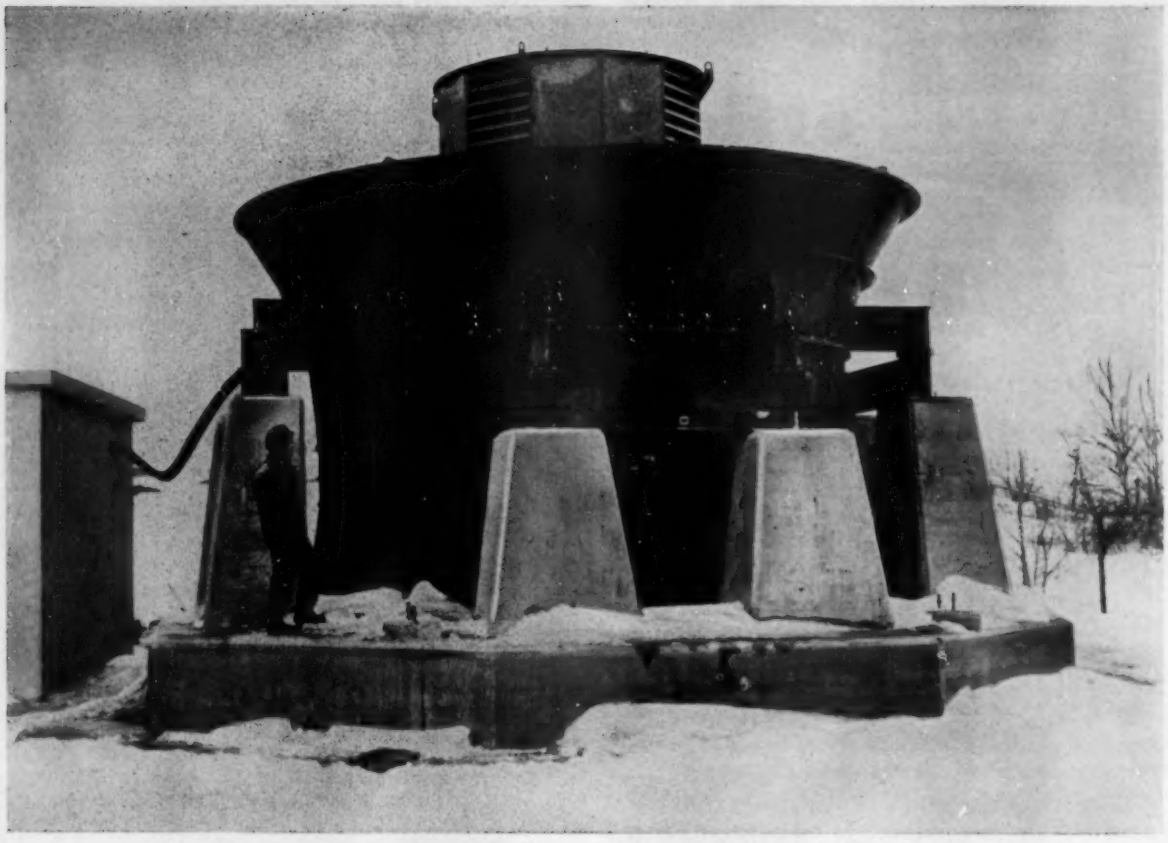
For intermittent duty, this totally-enclosed, non-ventilated model is available in frame sizes 284 to 505 inclusive. Above 505 frame, Allis-Chalmers offers its famous tube-type motor.



For continuous service, this tough, fan-cooled model is ideal. All enclosed motors can be furnished in standard enclosed or explosion-proof construction rated 55 C rise.

A-5180

ALLIS-CHALMERS



Huge fan makes mine its own air conditioner!

Stainless steel prevents failure of fan blades in damp corrosive atmosphere

Warms air in winter! Cools air in summer!

That's how the system diagramed at the right improves working conditions in Inco-Canada's big Frood-Stobie mine.

In winter, the fan drives frigid outside air through sprayed water in two tremendous stopes at the 300- and 500-foot levels. The water freezes... gives up its heat to warm the air.

In the summer, the fan drives warm outside air over the glacier-like accumulation of ice formed during the winter. As the ice melts, it extracts heat from the air. Miners work in comfort year 'round.

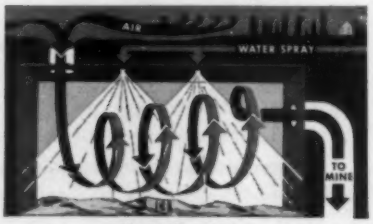
It's all done with one 750,000 cu. ft./min. fan.

This big, 16½-foot fan operates continuously day-in, day-out in all weather. And that outside air it handles contains dust and traces of corrosive sulphur dioxide.

To meet these conditions the 12 blades of this fan are stainless steel.

Stainless steel insures long blade life

Nickel-containing stainless steel has the resistance to corrosion, erosion and fatigue called for in mine and mine building air-conditioning systems and in other mine applications. It gives you extra strength and toughness, too. And it's easy to fabricate.



How it works

Consider stainless steel when you need long, reliable equipment performance and extra strength.

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

INCO NICKEL

NICKEL ALLOYS PERFORM BETTER, LONGER

Steep Rock to Concentrate Marginal Iron Ore

Direct-shipping iron ore mined at Steep Rock Lake, Ont., will be supplemented by lower grade material to be processed in a new $2 million concentrator. Steep Rock Iron Mines Ltd. indicates that waste stripped from the flanks of its high grade orebody contains enough ore to make processing economical. The concentrator will handle 750,000 tons of crude material and its product will be at least equal in grade to that of the regular mining operation.

Major Companies Hike Aluminum Prices

Major aluminum producers — Aluminum Co. of America, Reynolds Metals Co., and Kaiser Aluminum & Chemical Corp. — have raised the price of pig aluminum 1¢ to 26¢ per lb, effective Aug. 1, 1957. Other aluminum products follow with an average increase of about 4 pct. Reasons cited for the rise include higher labor costs, higher prices for materials, an increase in freight and power rates, bigger taxes.

Uranium Mill to Use New Process

The first mill of its kind to employ the continuous countercurrent extraction method (see page 1003) is nearing completion at Maybell, Colo. The 300-tpd mill is part of a processing unit being constructed by Southwestern Engineering Co. for Trace Elements Corp., a unit of Union Carbide Corp.

New Vein Discovered Near Radium Hill

A uranium orebody similar to the deposits now being worked at Radium Hill in South Australia has been found 400 yd from the older discovery, running parallel. New vein has been uncovered for over 400 ft.

Arctic Minerals Search Planned

A three-year expedition, massively equipped, will soon start out by ship to explore vast portions of the Arctic in the hope of finding uranium, gold, iron, and oil. Jointly financed by the Cyrus S. Eaton interests of Cleveland; List Industries Corp. of New York; and Scurry-Rainbow Oil Ltd. of Calgary, Alta., and Cleveland, the expedition will begin work on Baffin Island, located some 300 miles north of the Ungava iron deposits.

Kennecott Expects Better Second Half

Although first half earnings decreased substantially because of the drop in copper prices, Kennecott Copper Corp. expects good demand in the second half of the year, with market strength in the last quarter. Kennecott sold more copper in the first half of this year than in the comparable period in 1956, but a sag in earnings resulted from the drop in average price from 45¢ to 31¾¢ per lb.

Consumption Records Set by Steel Industry

Record use was made of certain alloying elements by the steel industry last year, according to the American Iron & Steel Institute. Included were: manganese, 746,266 tons; molybdenum, 13,763 tons; nickel, 47,608 tons; and titanium, 2,819 tons. More efficient use of blast furnace raw materials, however, resulted in a decrease in the amount of iron ore, scrap, mill cinder, limestone, and coke needed to produce each ton of steel.

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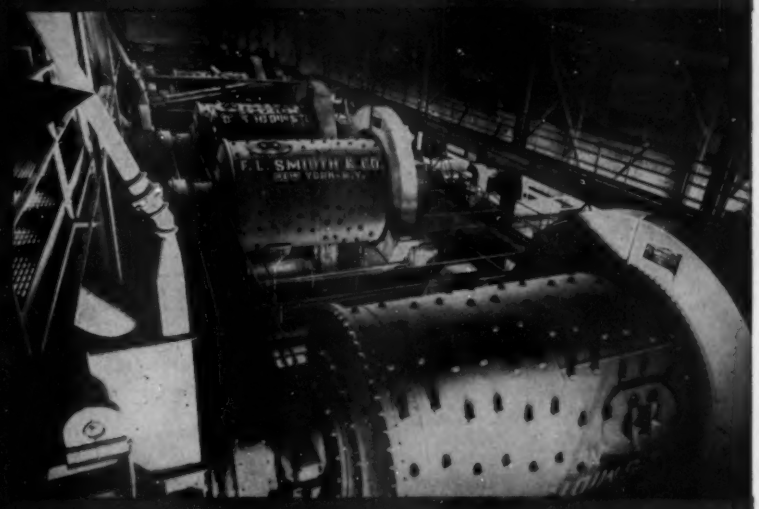
Rotary Kilns

For sintering, nodulizing, calcining, desulphurizing, oxidizing and reducing roasting—coolers, precoolers, preheaters, recuperators—and auxiliary equipment.

Grinding Mills

Ball mills, tube mills and multicompartment mills—open or closed circuit—wet or dry grinding also airswept for grinding and drying.

Over 1,000 Smidth Rotary Kilns and over 5,000 Grinding Mills supplied all over the world.



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made hard and tough to the core...for the long grind

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150 TON PER DAY LIME

ALL MAJOR PROCESSING EQUIPMENT DESIGNED AND BUILT BY KENNEDY

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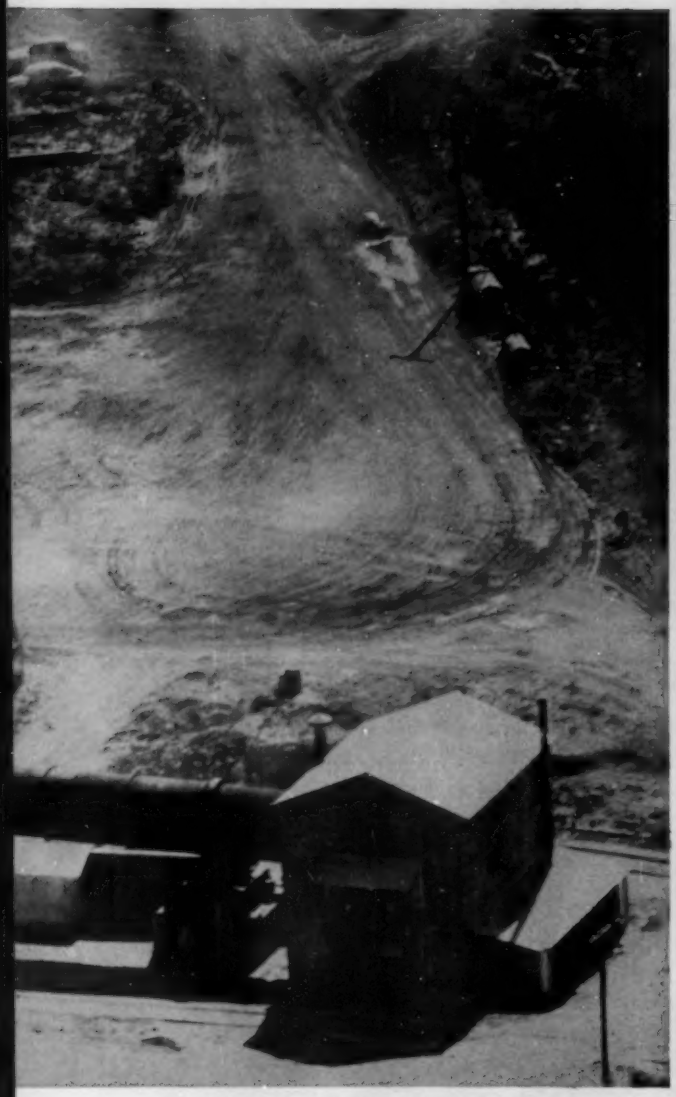
...at Texas Lime Company

Cleburne, Texas



TEXAS LIME COMPANY—150 Ton Per Day Lime Plant. 9' x 130' KENNEDY Rotary Kiln with Preheater and Deheater.

SEND FOR BULLETINS DESCRIBING KVS MACHINERY AND EQUIPMENT

CHECK √ *these Features for*

LOW FUEL CONSUMPTION

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MINIMUM LABOR REQUIREMENTS

- √ *Kennedy Stone Preheater*
- √ *Kennedy Short—2 tire rotary kiln*
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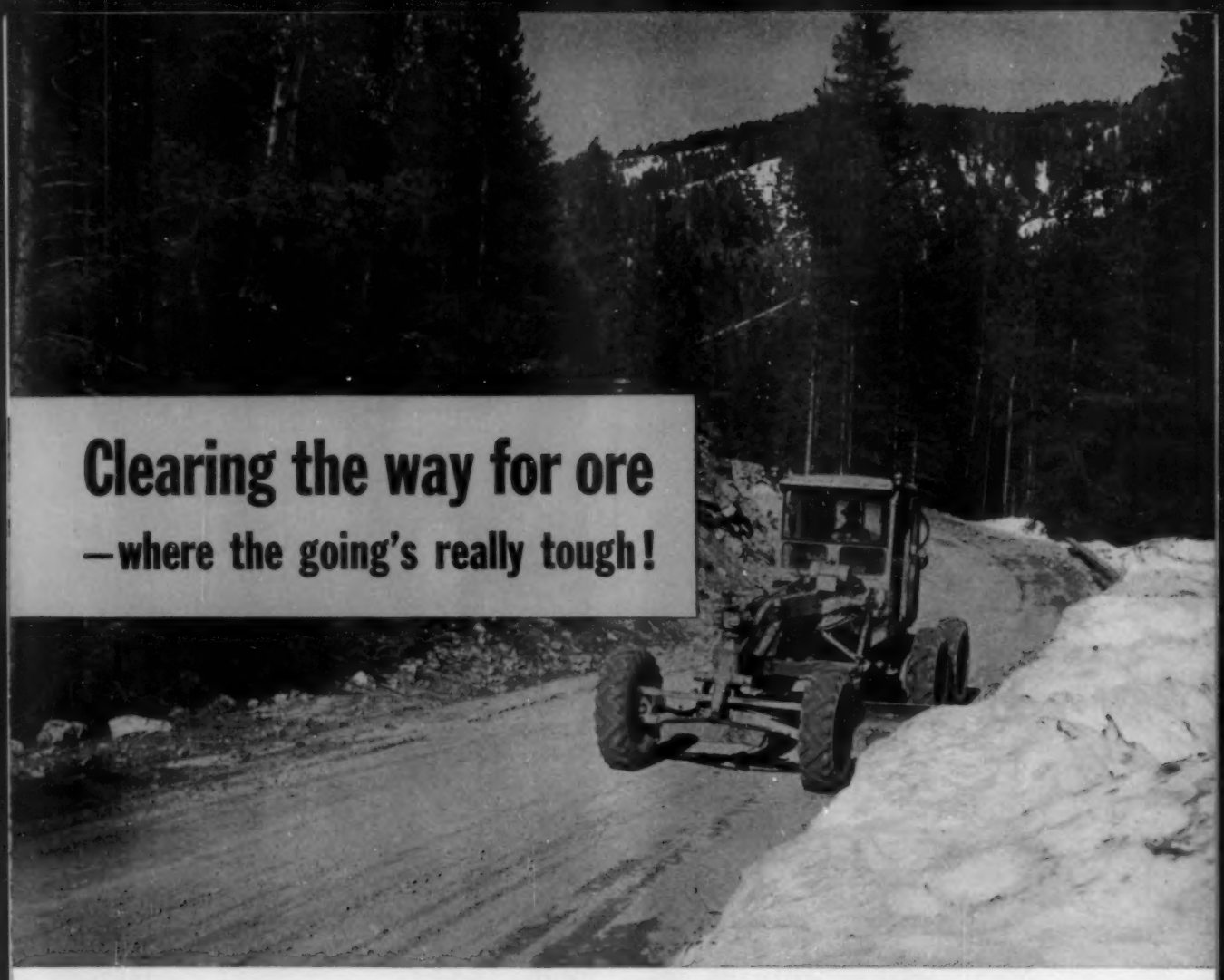
Similar installations throughout the world are noteworthy for their DEPENDABILITY and PROFITABLE OPERATION.

Consult us for a complete lime plant or any part thereof.



Clearing the way for ore
—where the going's really tough!

This is a mine haul road on Forest Service land about a dozen miles out of Lowman, Idaho. A CAT* No. 12 Motor Grader maintains 22 miles of it for Hi Dayley of Boise, under contract to Porter Bros. Corp.

Porter Bros. own two dredge mines near Bear Valley, working rare earths—uranium, monazite, titanium and other minerals. They need this road 12 months of the year. It's always a rugged maintenance job for the No. 12—mountainous, sandy, rocky. But this photo was taken in May, and during the winter the temperature dives to 56° below and the snows level off at around 11 feet. Still the No. 12 clears the way for the ore haul, day in, day out. When the snow is deep, the Domor Snow Blower is used to move the snow well back from the roadside.

The Cat No. 12 is a tough, smooth-working machine, made for rough duty like this. Its new oil clutch means better, easier operation and considerably less maintenance. Its controls are mechanical: fast and positive. It can swing that long-life blade from ditch cut to bank cut in less than a minute, without link adjustment. It features convenient in-cab starting, excellent visibility (notice the operator sitting down) and many other advantages. Its powerful 115 HP Cat Diesel Engine runs smoothly and faithfully on low-cost non-premium fuels.

For full details on the No. 12—product of the world's largest manufacturer of motor graders—see your Caterpillar Dealer. See him, too, for expert service, and for replacement parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

Gilsonite to Gasoline — First Refinery Opened

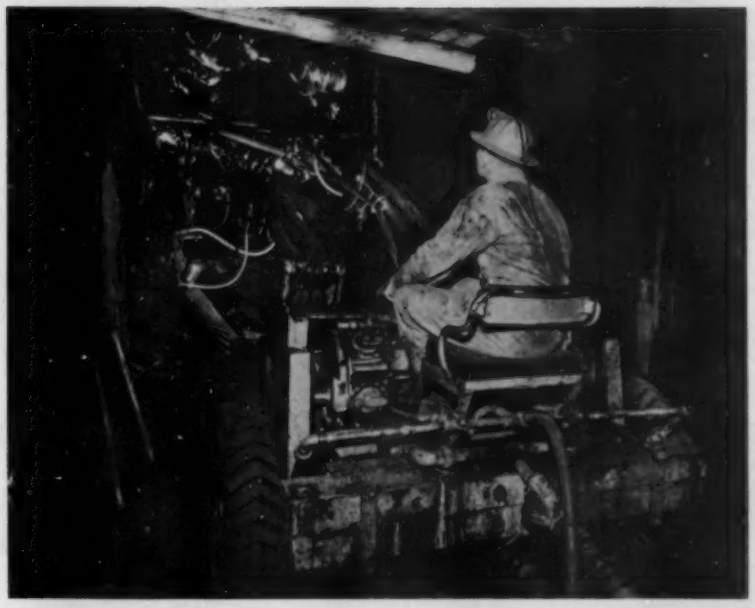
The first commercial plant to make gasoline from a raw material other than crude oil was formally opened at Gilsonite, Colo., on Aug. 2, 1957, by Secretary of the Interior F. A. Seaton.

Guests gathered at the new refinery near Grand Junction heard Secretary Seaton point out that this is the first privately financed commercial operation to produce high octane gasoline from a solid hydrocarbon, Gilsonite (Uintaite) ore, which is mined in Utah and transported over the first slurry pipeline to cross a mountain range.

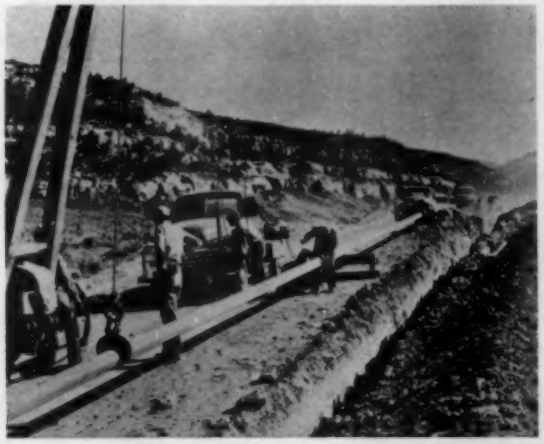
The other major product of the new $16 million undertaking of the American Gilsonite Co. of Salt Lake City, is high purity metallurgical coke—in demand by aluminum producers and other specialty carbon users.

The opening ceremony was climaxed by the release of a fountain of Gilsonite slurry which had passed through the 72-mile pipeline from the company's mine at Bonanza, Utah. Cost of the line was $2 million.

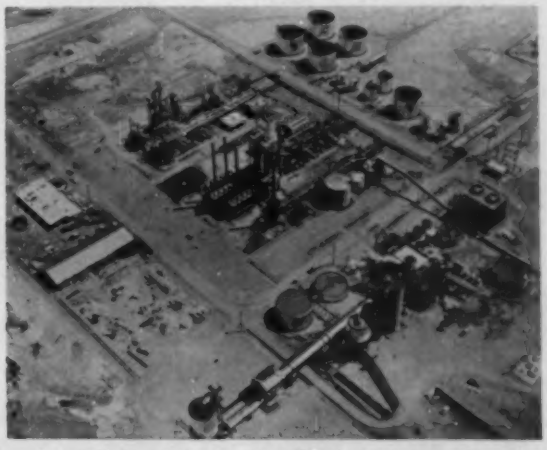
In a welcoming speech to visitors, E. F. Goodner, president of American Gilsonite Co., said, "This refinery



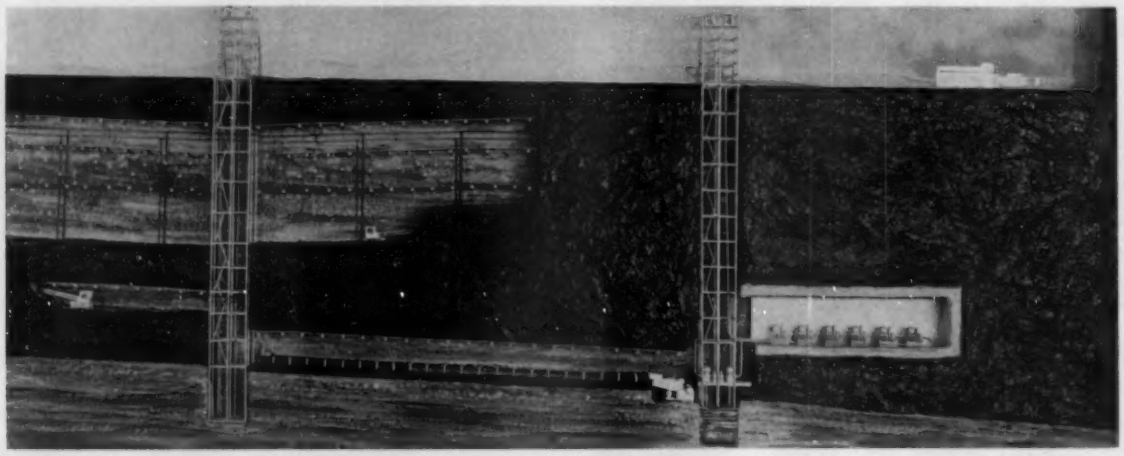
This cutting tool developed by the company consists of a long rotary drill armed with carbide-tipped teeth. To eliminate the explosion hazard of Gilsonite dust, the ore is constantly wetted by water passing through the teeth.



Laying the 72-mile pipeline from the mines at Bonanza, Utah, to the refinery. The 6-in. diam line carries a slurry of 35 pct Gilsonite—65 pct water. Discharge rate is 350 gpm.



An aerial view of the American Gilsonite Co.'s new coke and gasoline refinery at Gilsonite, Colo. About 150 people will be permanently employed on the 1200-acre site.



In mining Gilsonite, either a hydraulic or hydromechanical cutter, or both, is used to break up the ore. After cutting, the ore is washed down the drift to the main shaft, dewatered, and hoisted to the surface.

proves the economic feasibility of deriving petroleum products from other than conventional sources. We believe this is opening up unlimited possibilities for the vast quantities of petroleum-like materials, now lying unused, in which this area abounds."

Pipeline Troubles Solved

The unique slurry-carrying pipeline caused some difficulty during its trial runs, but the problems were quickly eliminated. A major factor in the design of the line was the particle size of the Gilsonite in the slurry at the mine end. Although the pumps used to propel the material could handle particles of ¼-in. size, results improved dramatically with reduction of the mineral to 8-mesh size. This smaller size also decreases degradation in transit, simplifies dewatering, and makes it easier to maintain a suspension through the line.

The pipeline is designed for continuous flow, and will be shut down only after all the slurry is flushed from the system. Experience shows that so long as adequate velocities are maintained, the slurry can be continuously circulated without build-up of solids.

With a daily delivery of 700 tons of ore through the pipeline, the refinery turns out 275 tpd of high purity electrolytic coke, quantities of fuel oil which are burned for plant power, and 54,600 gal of high octane gasoline.

Frozen Ore Cars Quickly Thawed With Infrared Heaters

A new technique for thawing ore cars in frigid weather was demonstrated in Cleveland recently. A rail car placed under typical winter conditions was thawed and dumped in a matter of minutes through the use of a gas infrared generator system. To simulate typical winter conditions, the rail car had been loaded with 80 tons of No. 12 iron ore. This, in turn, was frozen to a depth of 6 to 8 in. on all sides, top, and bottom.

It is expected that the new method will facilitate winter shipment of ore and coal in the North by cutting down the high cost of thawing frozen rail cars. In many cases, the present cost of thawing prohibits normal dumping during winter operations even though the cars cannot be handled economically on reaching their destination.

The equipment employed in the newly shown technique was a bank of Perfection Schwank gas infrared generators made by Perfection Industries, a division of Hupp Corp. According to the company, a coal handling firm already using the heaters has about doubled their daily car thawing rate and decreased their normal daily fuel cost by approximately 40 pct.

The Cleveland demonstration was made possible with the cooperation of the Duluth, Missabe, & Iron Range Railway Co.

At Edgemont, South Dakota, for

MINES DEVELOPMENT, INC.

...one of the first Resin-in-Pulp uranium recovery plants.

Complete engineering, design and construction by

WESTERN KNAPP ENGINEERING CO.

A DIVISION OF WESTERN MACHINERY COMPANY

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Atlas Copco Terrier

The drill with versatility *plus*

One Terrier does the work of a number of specialised drills. Because you no longer have a lot of drills lying idle, the Terrier cuts costs considerably on mining and construction jobs. It can be used for boulder blasting, trimming ceilings and walls after blasting, plug-hole drilling in concrete; timbering, terracing, trenching and prospecting. It will drill holes for all sorts of purposes, including fixing ventilation tubes or electric cables, aligning the centre line in drifts and tunnels, installing reinforcement netting for spraying tunnel walls with concrete. It is easily converted into a scaler. It's light (as little as 18¼ lbs.), fast (it sinks a 12″ hole in 30 secs.) and economical (it uses only 44-53 cu. ft./min. of air).

The right steels for the Terrier are of course Sandvik Coromant ¾″ steels or plug steels.

Boulder blasting with the Terrier LH. (Left).
Plug-hole drilling in concrete. (Below, Left).
Scaling with the Terrier LTS (note the convenient leg support). (Centre).
Survey hole drilling, using the BMK 11 pneumatic pusher. (Right).

Write, phone or cable today for further details to any of the addresses below:

Atlas Copco

EASTERN *P.O. Box 2568 Paterson 25, N.J.* **PACIFIC** *930 Brittan Av, San Carlos, Calif.*
CANADA *Montreal Airport, Quebec.* **MEXICO** *Apartado Postal 56, Torreon, Coahuila*

This Bucyrus-Erie 770-B walking dragline is mining phosphate matrix near Bartow, Florida. It swings a 20-cu. yd. bucket on a 195-ft. boom.

Bucyrus-Erie Walking Draglines Move Overburden High, Wide and THEN SOME

Not only do Bucyrus-Erie walking draglines move overburden *high* to the top of spoil piles, but they go down deep for it, too, when necessary. And in addition to moving it high and wide, they traditionally move it *economically*. This ability to move big yardages at consistently low cost has made them preferred for stripping operations everywhere.

Modern front-end design that combines great strength with light weight contributes to outstanding performance—by permitting Bucyrus-Erie walking draglines to swing big buckets on long booms.

Exclusive Bucyrus-Erie walking mechanism permits smooth, fast moveups, easy maneuvering to most advantageous working position. These features plus month-after-month dependability and low maintenance are your assurance of high volume, economical production.

For moving big yardages economically, choose from the world's largest selection of walking draglines. Contact Bucyrus-Erie Company for full information. 142137

BUCYRUS ERIE

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Dirt, Corrosion, Low Voltage Problems?

Allis-Chalmers Size 6 starter, NEMA 1 enclosure.

the answer:

Allis-Chalmers "dc operated" ac contactors*

Dc operators in Allis-Chalmers control assure dependable performance because they are not affected by dirt or corrosion on the armature face. Positive magnetic operation reduces contact pitting — eliminates hum and chatter—prolongs mechanical life. The operator picks up at 65% of rated voltage — holds in with as little as 35%.

For Any Low Voltage, High Horsepower Application . . . Allis-Chalmers Modern Control — Sizes 4, 5 and 6

Advanced Electrical Design

ACBO arc-centering blowout sharply curtails arcing time, greatly prolongs contact and chute life — without blowout coils.

Simplified Mechanical Design

Streamlined clapper-type construction permits natural arc rise in arc chute. Sensible enclosure dimensions provide ample wiring space. Easy accessibility simplifies maintenance.

For detailed information on this complete line of modern control, call your A-C Control Distributor or A-C District Office. Or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

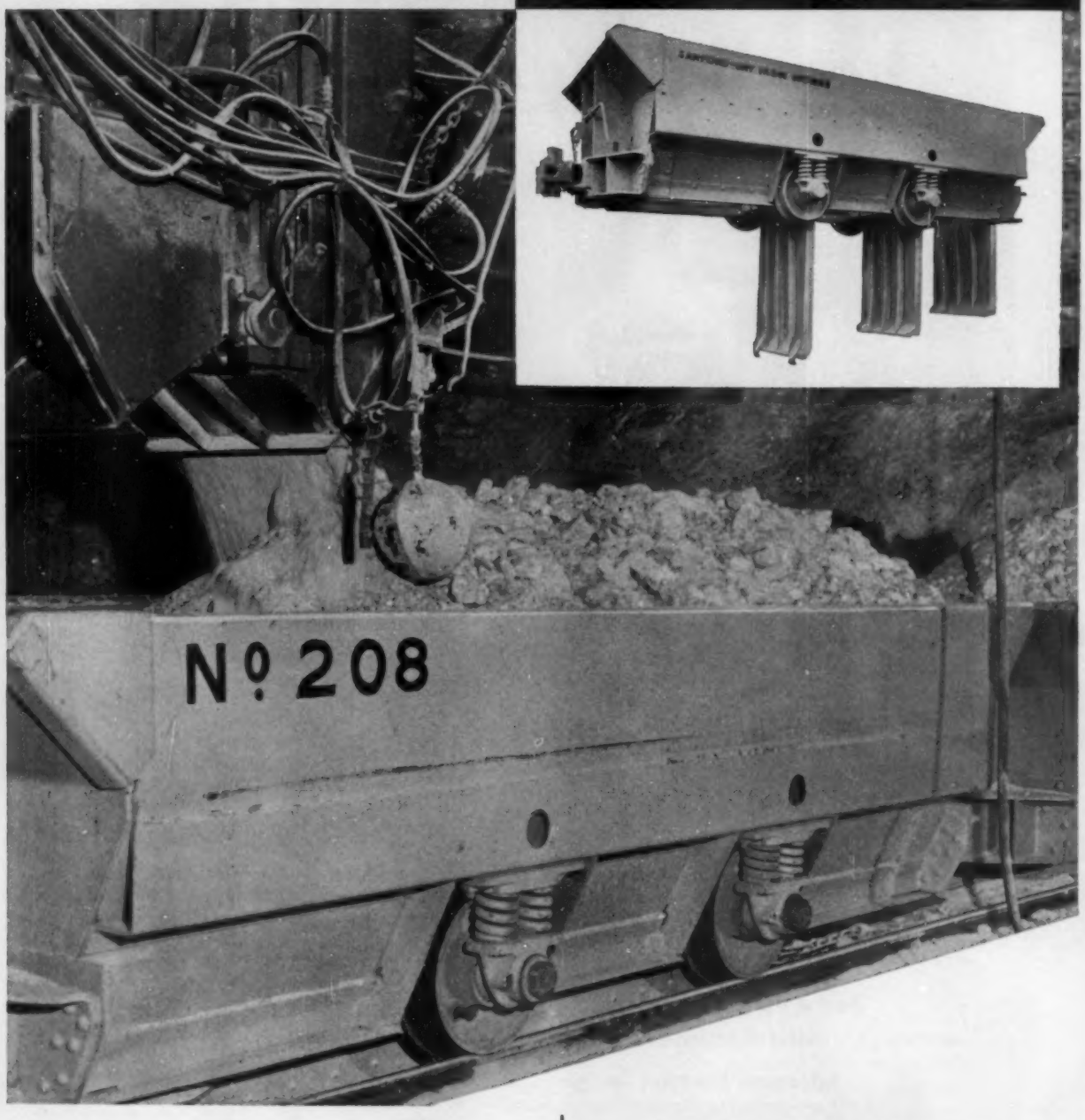
*Self-contained ac to dc circuit. Standard in Size 6, optional in sizes 4 and 5.

ALLIS-CHALMERS

A5372

ACBO is an Allis-Chalmers trademark.

These S-D AUTOMATICS



SANFORD-DAY

Knoxville, Tennessee

"SUPER MARKET FOR MINE CARS" — *all types* * PRECISION WHEELS * "BROWNIE" HOISTS, CAR RETARDERS, SPOTTERS, PUMPS AND OIL SPRAY SYSTEMS * GISMO SELF-LOADING TRANSPORT that loads *(mucks)* in development or production . . . transports . . . supports 2 to 5 jib mounted drills . . . back fills . . . moves boulder rocks . . . makes its own roadways and cleans up completely — a new method of hard rock mining offering a tremendous reduction in cost per ton!

have been in service at U. S. Potash 3 years...working 363 days per year, two shifts per day on a seven-mile run!

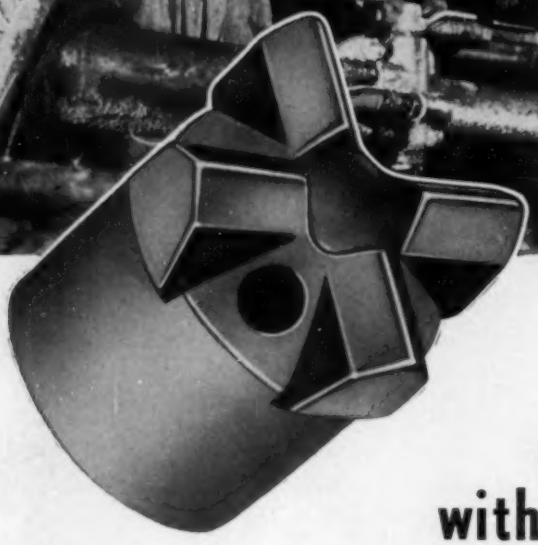
Another example of efficient main-line haulage with S-D "Automatic" Bottom Dumping Mine Cars!

"Because of their low center of gravity and balanced rugged construction, they hold the track exceptionally well at speeds up to 30-miles-per-hour," reports Mr. Earl H. Miller, resident manager of the Carlsbad, N. M., mining operation of United States Potash Company, Division of United States Borax & Chemical Corporation.

"Also," Mr. Miller continues, "the door operation is very good, allowing the cars to do a good job of self-cleaning." How does the maintenance costs of these cars compare with conventional type ore cars? "We have had very low maintenance costs on the S-D 'Automatics' compared to others we are using."

Note in pictures above and on page at left that mining management at U. S. Potash have further mechanized their main-line haulage with an automatic loading station. We are understandably proud that S-D "Automatics" were chosen for this U. S. Potash operation that incorporates the latest developments in modern simplicity and efficiency. In addition to this installation, S-D "Automatics," like the car illustrated at right, are hauling hard rock in several western mines at tremendous savings! Write us today for complete information. *Sanford-Day Iron Works, Inc., Knoxville, Tennessee*

1/4 TO 1/2 TON MORE CAPACITY
Twin Latches FOR SAFE AND SURE LATCHING
SANFORD-DAY IRON WORKS
Safety Sealed AGAINST DUST LEAKAGE



Four Ways to Save Money with CRD One-Use Bits

1. You drill faster with low-cost Le Roi-Cleveland CRD one-use bits because they have a special offset gauge feature which permits the use of thinner wings, and a steeper reaming angle. Binding is greatly reduced, and ample clearance is provided for cuttings.

2. You have less drill-steel breakage with Le Roi-Cleveland CRD one-use bits. The method of bit attachment eliminates threads on the drill rod. And since a drill rod is only as strong as the root diameter of its threads, the tapered, *threadless* CRD's give you a stronger, power-saving union, and longer drill-steel life. Other savings result from reduced handling and reconditioning costs.

3. You have less wear and tear, too. Rifle bars, rifle nuts, and chucks will last longer because CRD's are designed to reduce binding and ease strain on rotation parts of your drills.

4. They cost less, initially. CRD's cost less than 25¢, half as much as comparable multiple-use bits. There's a big saving in time and labor spent handling bits, too. CRD's knock-off, throwaway use eliminates unscrewing, and all the time-consuming traffic between operator and bit shop.

It costs practically nothing to try them. You don't need to invest in special threading or reconditioning equipment when you use Le Roi-Cleveland CRD one-use bits. Satisfy yourself that they can save you money. Get a can today, and start cutting your drilling costs right away.

LE ROI Division of Westinghouse Air Brake Co., Milwaukee 1, Wisconsin, manufacturers of Cleveland air tools, Tractair, portable and stationary air compressors, and heavy-duty industrial engines. Write us for information on any of these products.

AT-78

CYANAMID

REAGENT NEWS

"ore-dressing ideas you can use"

Settling Solids with AEROFLOC® Reagent Reduces Downtime and Maintenance Costs in Underground Pumping System

For several years, West Driefontein Gold Mining Company, Ltd. in South Africa has used AEROFLOC 3000 Reagent to flocculate solids in their underground sumps and thus eliminate excessive pump-wear. Only 65-70 pounds of AEROFLOC 3000 Reagent per day are required at this gold-uranium operation to treat approximately 6½ million gallons of water—a concentration just slightly over 1 ppm.

Formerly, treatment with lime caused scale deposits in pumps and pipelines, requiring acid descaling of the pumps every 250 hours. Downtime, labor, supervision and parts replacement were excessive.

Since using AEROFLOC 3000 Reagent, scaling has been eliminated. Pumps are now opened for inspection after 10,000 hours operation. Downtime and labor costs have been cut markedly. In addition, sump overflow is now clear. Additional slime, previously not settled with lime, collects in the sumps, providing a small increase in gold recovery.

If you are interested in testing the AEROFLOC Reagents for settling underground sludge at your operation, we will be pleased to send samples. Write to our nearest office or technical representative.

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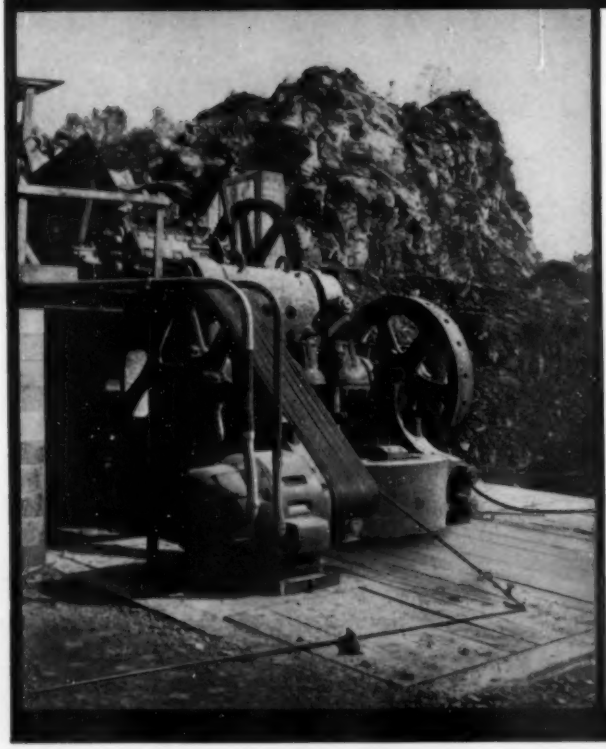

the profit-wise operator BUYS TRAYLOR JAW CRUSHERS for the same reason

For over a half century, producers have specified Traylor-made Jaw Crushers to insure extra hourly production with lower operating costs per ton. There are four types of Traylor-made Jaw Crushers to fit every primary breaking requirement. Feed openings range from 8″ x 12″ to 60″ x 84″; capacities from 4 to 1000 tons per hour. For bulletin on the Traylor Jaw Crushers best suited to your needs, write stating product size and capacity desired.

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equipment for peak performance

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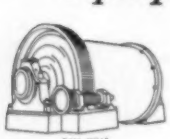
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ROTARY KILNS

PRIMARY GYRATORY CRUSHERS

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SECONDARY GYRATORY CRUSHERS

"Modern Copper Concentrator at Silver Bell, Ariz., for American Smelting & Refining Company"

THE PLANT AND YOUR FUTURE

Planning for successful operation begins with preliminary designs and cost estimates. From start to production, assign Stearns-Roger the task—one order, one responsibility for design, engineering, procurement and construction. For new plant or modification,

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Stearns-Roger Engineering Company, Ltd., Calgary, Alberta

Steep Rock Insulates to Ward Off Work-Stopping Cold

Steep Rock Iron Mines Ltd. met a new problem when it tried to evade the one posed by extreme low temperatures at its big new mine in Atikokan, Ont.

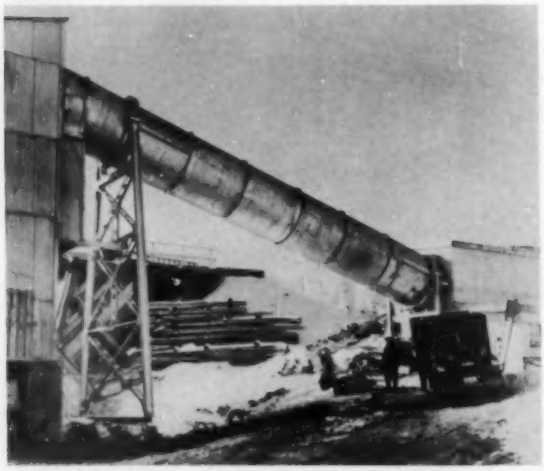
Steep Rock decided that best efficiency would result from working its high grade iron orebody as an open pit in fair weather and as an underground operation in the months when the Canadian winter pushes temperatures down as low as —50°F. Wet ore coming from underground, however, caused trouble when conveyed in the frigid surface air.

In the winter operation, a conveyor belt is used to carry ore to a loading tipple above ground. From the point where it emerges from the ground, to the tipple, the belt is enclosed in an 8-ft diam steel tube. The difficulty arose when moisture condensed on the cold surface of the tube, building up heavy frost layers more than 6 in. thick, and seriously interfering with conveyor operation.

At first the tube was heated from within by a steam pipe and covered with a waterproofed insulation, but the combination of severe moisture inside and extreme cold outside caused failures.

The steel tube was reinsulated, this time on the inside, with an insulating material composed of sealed glass cells which is unaffected by moisture. High compressive strength of the material (Foamglas by Pittsburgh Corning Corp.) also permitted pouring a concrete wearing floor for the lower portion of the tube directly over the insulation.

A 60-ft long tube was first insulated and put in use during the winter of 1954-1955. It proved so successful that another tube, 260 ft long, was similarly insulated. Other applications are being considered.



LEFT: First insulated conveyor tube at Steep Rock Iron Mines Ltd. was this 60-ft long unit running from mine entrance to tipple. RIGHT: Cellular glass insulation being applied. Pins were stud welded to inner surface which was then coated with asphalt primer. A layer of 1½-in. thick Foamglas was next applied with hot asphalt. Insulation blocks were also impaled on the pins and secured with spring clips. Another 1½-in. layer was then applied using hot asphalt. A final finish of mastic was then trowelled on. On the bottom of the tube the insulation was mopped on with hot asphalt and concrete poured directly over it.

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PENNSYLVANIA WATER AND POWER CO.

...a 190 ton per hour flotation plant for reclamation of fine coal from river silt.

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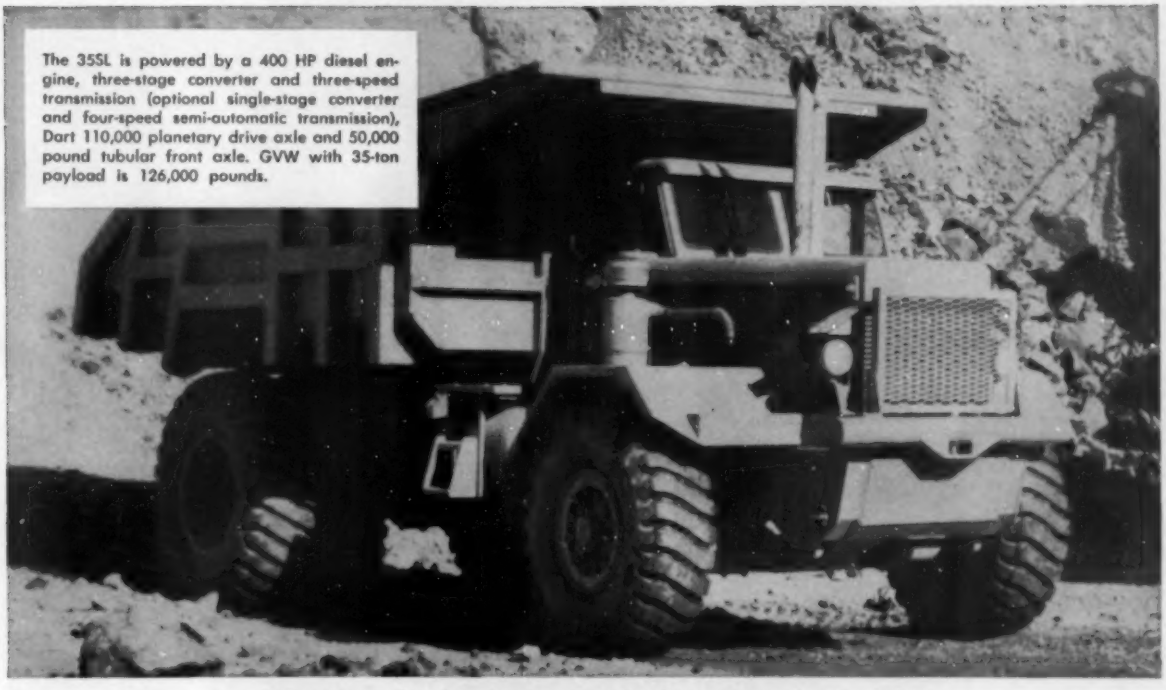

The 35SL is powered by a 400 HP diesel engine, three-stage converter and three-speed transmission (optional single-stage converter and four-speed semi-automatic transmission), Dart 110,000 planetary drive axle and 50,000 pound tubular front axle. GVW with 35-ton payload is 126,000 pounds.

WHAT THEY ARE SAYING ABOUT THE

DART 35SL

AFTER THE FIRST YEAR

SUPERINTENDENTS: *"Costs are down . . . Hauls a big load . . . And on two axles, highly manueverable . . . Lots of power . . . Less tire wear."*

MASTER MECHANICS: *"Rugged construction . . . It can take it . . . Less parts to maintain . . . Easy to work on."*

DRIVERS: *"Easy to steer . . . Very stable . . . Excellent visibility . . . Quick spotting under shovel."*

Dart 25SL powered by a 300 to 335 HP diesel engine, three-stage torque converter and four-speed transmission (optional single-stage converter and four-speed semi-automatic transmission), Dart 100,000 pound planetary drive axle and 25,000 pound tubular front axle. GVW with 25-ton payload is 97,000 pounds.

Dart 50T powered by a 400 HP diesel engine, three-stage converter and three-speed transmission (optional single-stage converter and four-speed semi-automatic transmission), Dart tandem planetary rear axles of 100,000 pounds capacity each, and front axle of 35,000 pounds capacity. GVW with 50-ton payload is 180,000 pounds.

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HEAVY DUTY TRUCKS EXCLUSIVELY SINCE 1903

DART TONNAGE ENGINEERED TRUCKS

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SUBSIDIARY OF THE CARLISLE CORPORATION

D-332

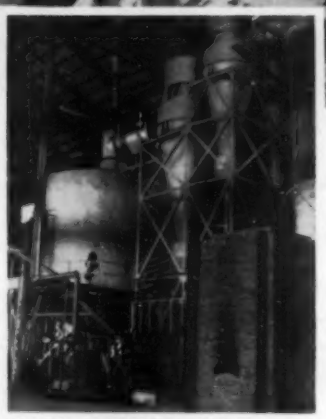
Dowa Mining's Kosaka hydro-metallurgical plant where Dorrco FluoSolids System roasts 83 metric tons of complex copper-zinc concentrates per day.

Fluidization — key to maximum utilization in Japan

Processing copper bearing pyrrhotite ore, the Dowa Mining Company at the Okayama, Japan plant is producing . . . and all from the same raw material . . . sintered iron ore for blast furnace use, cement copper and sulphuric acid.

Of major importance in this unique installation is the Dorrco FluoSolids System, consisting of two 20 ft. dia. Reactors plus auxiliary equipment. Utilizing the proven principles of fluidization, the crushed raw ore is roasted under controlled conditions in the System providing SO_2 gas for contact acid manufacture. Roaster calcine is acid leached for copper recovery and leach residue is sintered as blast furnace feed.

The Dorr-Oliver research, design and engineering staffs and our Associates in Japan, Sanki Engineering Co. Ltd., of Tokyo, have collaborated with Dowa Engineers before. At Dowa's hydro-metallurgical plant in Kosaka, Japan, Dorrco FluoSolids System is a prime factor in the world's first successful roasting of copper and zinc with electro winning of both metals. In the Okayama installation as at Kosaka, manufacture of the FluoSolids Reactors and a number of components in Japan with auxiliary equipment furnished from the U. S. proved to be most advantageous to Dowa.



One of two 20 ft. dia. FluoSolids Reactors roasting 235 metric tons per day of crushed pyrrhotite ore at Dowa's Okayama Plant.

This is but another example of how the flexibility of the Dorr-Oliver Worldwide engineering organization can work to the advantage of a client. It can work for you . . . For detailed information on D-O equipment and services involving the separation of finely divided solids in suspension or fluid techniques, drop a line to Dorr-Oliver Inc., Stamford, Connecticut.

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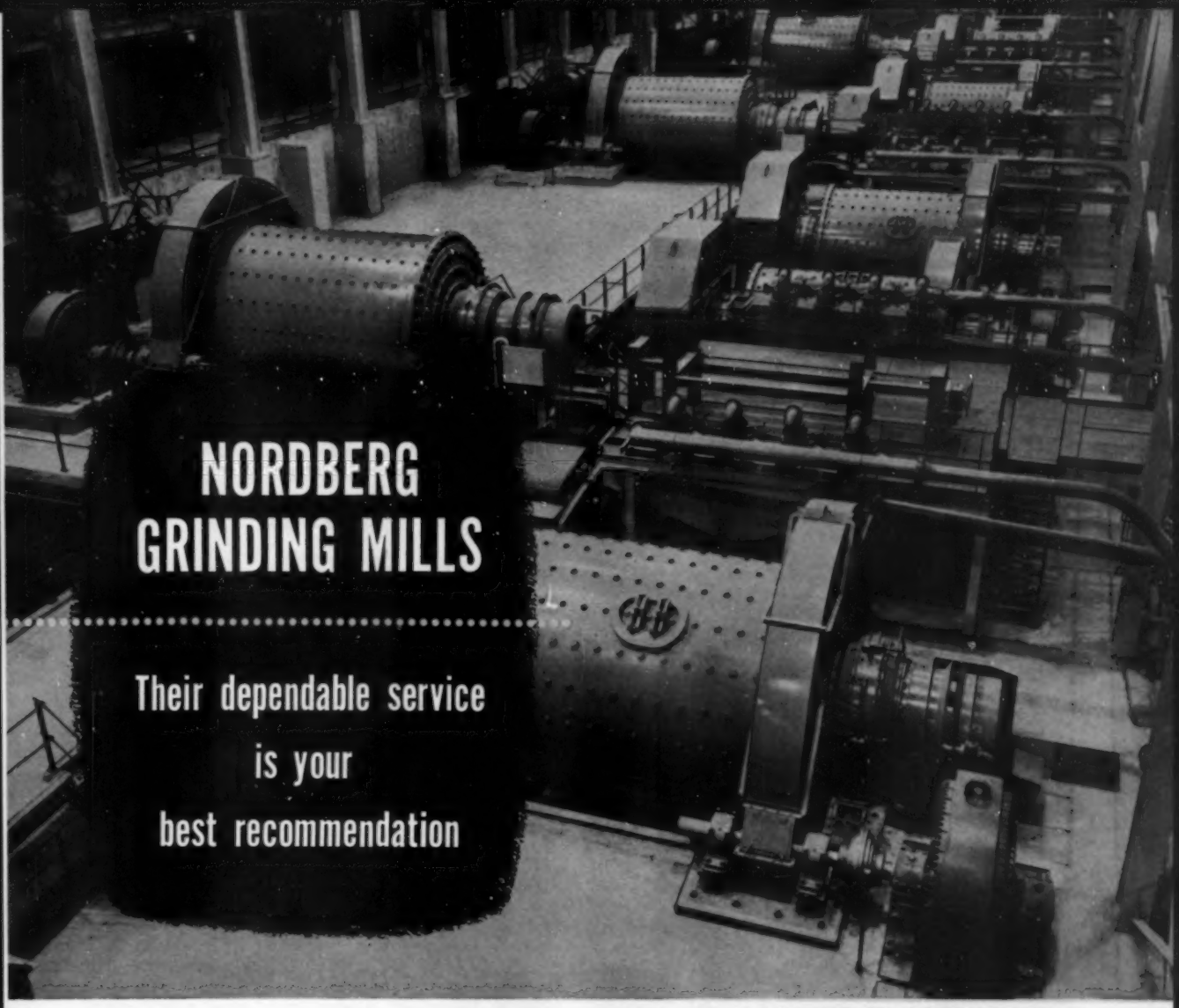

(Above): *Four Nordberg 10½'x16' Rod Mills and eight Nordberg 10½'x14' Ball Mills installed in a large concentrating plant for the reduction of hard, abrasive "Taconite" ore.*

In the mining industry, thousands of service hours are required to prove true dependability . . . a significant reason why Nordberg Grinding Mills now are being selected for installation in many large ore reduction plants.

Nordberg Grinding Mills are designed and built for wet or dry grinding of metallic and non-metallic minerals. Sizes range from 6 to 13 feet diameter and up to 50 feet in length in Rod, Ball, Pebble, Tube and Compartment types.

Of advanced engineering and quality construction, Nordberg Grinding Mills assure trouble free and low cost operations. Consult an experienced Nordberg engineer next time you have a grinding problem. *NORDBERG MFG. CO., Milwaukee, Wisconsin.*

SEND FOR THIS NEW BULLETIN

This new Nordberg Bulletin 232 fully illustrates and describes the full line of Nordberg Grinding Mills for the efficient, low cost processing of ores and industrial minerals. Write for your copy today.

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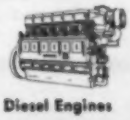

Diesel Engines

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GM157

CURRENT unbalance between production and consumption of slab zinc, the drop in zinc prices, and the "wait and see" attitude of zinc consumers notwithstanding, 1957 will end up among the top consumption years in the industry's history, predicts J. L. Kimberly, executive vice-president of the American Zinc Institute.

The estimate was based on the consumption figures already available for the first five months of the year and conservative industry estimates for the balance of the year. Preliminary USBM figures through May 1957 show consumption at 401,185 tons. Even if consumption remains low through August and increases slightly during the last four months of the year, as it has done in the past, Kimberly said, the total consumption figure will be on the order of 950,000 tons.

Trend lines based on the major uses of zinc are particularly promising, he said, and even though the years 1956 and 1957 have strayed from the boom time of 1955, the long range picture is well upward. Kimberly noted that there is no well established metal or other industrial material, which is not subject to fluctuations after its basic market position has been established. "This is not to say that the industry is complacent about either the recent world-wide overproduction of zinc metal, or the obvious need to find new and expanding markets for zinc. It is to say that the demand for zinc is continuing at high levels and will grow as overall production in the economy rises."

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COLUMBIUM and tantalum use is on the upswing if a 1700 pct increase in domestic concentrate production is any indication. While these rare metals are produced in small volume, they are finding increasing industrial use like others formerly almost unknown.

The domestic industry was stimulated last year by an AEC bid for 15,000 lb of high purity columbium, but world output suffered a 17 pct decrease as a result of cessation of U. S. orders. A heavy increase in domestic mine shipments of concentrates resulted from first year production of a euxenite placer mine at Bear Valley, Idaho. Turning out its brown-black ore, the mine accounted for more than 99 pct of the columbium-tantalum material shipped in 1956.

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IF EXPECTATIONS voiced by the AEC are realized, the U. S. will double its output of uranium oxide by the end of 1958. The 12 privately owned mills in operation are presently capable of producing 4200 tons of concentrates annually, compared with the capacity of 3400 tons available in the last six months of 1956, and that of 2600 tons in the first half. Operating at capacity, the mills process 9210 tpd of ore, daily dressing it to some 23 tons of refined oxide.

This production, added to that of the ten more mills now under construction or projected, will be increased to 45 tons of oxide daily by the end of 1958 when production schedules are reached. According to the 22nd semiannual report of the AEC, "The two categories of mills, operating and projected, will together handle 18,305 tons of raw uranium ore a day." The report noted, however, that ore production has fallen off for the first half of 1957 to about 1.62 million tons, from the 1.66 million tons produced in the last half of 1956. Some 1.34 million tons were mined in the first half of 1956. In addition, no significant new producing areas were found this year; and there was no essential change in the number of uranium mines.

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NEWSPAPERS in New York have generously sprinkled their pages lately with such headlines as: Inco is Disappointed U. S. Won't Buy Metal; GSA Rejects Inco Contract for New Nickel Output; International Nickel Will Have to Seek New Markets, Official Says. The trigger was the refusal by the General Services Administration to enter into contract for purchase of any unsold nickel produced by International Nickel Co. of Canada Ltd.'s two new mines in Manitoba. Inco had submitted the request in response to a U. S. offer of purchase contracts to assist new nickel producing facilities.

Inco viewed the turn of events with understandable regret. Company president H. S. Wingate said that: "For the government not to extend to the new nickel producing area of Manitoba any protection against the risk of surplus nickel production such as it has decided to make available for the new nickel producing area under development at Moa Bay in Cuba, comes naturally as a disappointment to the company." He commented further, however, that to consumers it was "very good news" since they need no longer worry about the stockpile draining away needed metal. Also, he said, new uses can be found to take up the extra supplies resulting from the Manitoba and other expansions.

The Manitoba operation will not be affected by the action, according to Inco. By 1961 company production will have increased to 385 million lb from the 1956 total of 285 million lb, with the development of the Canadian Mystery-Moak Lake nickel area.

Attorney General H. Brownell, Jr. reported to the White House and Congress that the U. S. now relies on Inco for only about 66 pct of its primary nickel needs instead of more than 95 pct as it did in 1950 when the Korean War began; and this was the result of reactivating the U. S.-owned nickel plant at Nicaro, Cuba, and the entry into the field of new U. S. producers with the help of several government grants. As of last spring, his report said, the Office of Defense Mobilization had allocated almost $850 million to the nickel expansion program.

Mr. Brownell said that Inco in the past had followed "aggressive and sometimes anti-competitive" policies which enabled it "to be the controlling factor in nickel production." Inco, under the control of U. S. capital and once headquartered in New Jersey,

he said, could not be investigated under U. S. anti-trust laws because it had moved to Canada and incorporated there. "The most important anti-trust difficulty was, and indeed still is, the unavailability of Inco's business records," he added.

Commenting on Inco's percentage decrease as the major supplier, officer Wingate said: "Inco's efforts are not directed to its relative position now or in the future. Its purpose and determination is to develop its producing potential as fully and as efficiently as possible in the interests of its shareholders, its customers, and the Canadian economy." He said also that the U. S. decision has "had a good effect, in that it has made us realize that we have a marketing job to do."

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NATURAL hazards above ground confront the mining man from time to time, causing varying degrees of discomfort and sometimes more than a little extra work. Troubles range from chiggers under the collar to flash floods and worse.

A heretofore unheard of case, however, reaches us through the Alaska Department of Mines and we are retelling it here. It seems that a crew of diamond drillers working high on the slope of one of Alaska's dry mountains was swearing with all their professional skill over not being able to keep water flowing through a new supply line of air-dropped plastic pipe. The insignificant trickle reaching the work site forced the operation to a stop, and the crew's helper was dispatched to locate the trouble. He quickly returned at a brisk run, white-faced, to report that a bear was chewing on the pipe. The line was quickly patched, but the thirsty bruin has returned a number of times to tap his newly found water-bearing bonanza.

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BIGGER U. S. reserves of chromite and a large ore potential such as recently reported by Interior Secretary F. A. Seaton will be small help for substantial national needs. Most of the material is subgrade for economical mining or beneficiating as needed. Total measured, indicated, and inferred reserves are presently estimated at about 3.5 million long tons of contained chromium oxide. The Geological Survey's last report (1945) estimated 2 million long tons, but this has been increased by revisions of a number of area reserves, notably the Montana deposits.

If the U. S. were to depend solely on domestic sources, the mines would find difficulty in supplying sufficient material for a 10-yr supply at the present rate of consumption; and at that the unproven potential ores would be needed as well. In 1956 the U. S. used about 740,000 tons of oxide in all grades of ore. The annual average in the last five years was 530,000 tons. At this average rate, our measured and indicated reserves would last two to three years, and inferred ore another three to four years.

Major domestic areas of promise for additional exploration, notes the survey, are those of the Stillwater complex in Montana and the beach sands of the Oregon coast.

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TOTAL U. S. iron-ore resources are put at about 75 billion long tons of crude ore by the latest report of the Geological Survey.

Since the 1955 summary of iron resources, the estimated total of major deposits has been increased by more than 25 billion long tons. Partly the result of further exploration and more complete data, the increase stemmed principally from the inclusion of additional low grade material in the Lake Superior area.

According to the Survey, reserves constitute about 10 billion long tons of the total. Of this about 5.5 billion long tons fall into the category of direct-shipping ores and concentrates obtainable from low grade ores. The 65 billion tons remaining, says the report, is potential ore which could probably yield some 25 billion long tons of concentrates and a small amount of direct-shipping ore.

The table below indicates that regional reserves of direct-shipping ore and concentrates are roughly proportional to production except in the Southeast, where production is relatively lower. The Western region and Central and Gulf region appear to be seriously deficient in potential ore to maintain their present relative production rates, but data for iron ore resources in these regions is probably less complete or more conservatively interpreted than for other regions which have for many years been the principal iron ore sources. The Lake Superior and Southeastern regions have the major share of reserves and potential ore, and the greater part of our domestic iron ore must continue to be produced from these regions.

U. S. Production of Direct-Shipping Iron Ore and Concentrates, and Estimated Percentages of Iron Ore Resources

Regions and States in Current Production	Production 1951 to 1955 (from USBM)		Estimated Resources	
	Long Tons	Percent of Total	Reserves (Direct-shipping Ore and Concentrates), Pct	Potential Ore (Most Requiring Beneficiation), Pct
Northeastern New York, New Jersey, Pennsylvania	24,980,000	4.9	3.5	4.4
Southeastern Alabama, Georgia	37,620,000	7.3	11.2	17.3
Lake Superior Minnesota, Michigan, Wisconsin	410,510,000	80.1	73.6	77.3
Central and Gulf Texas, Missouri	5,770,000	1.1	0.9	0.2
Western Wyoming, Utah, Nevada, California	32,930,000	6.4	8.7	0.8
Total	511,760,000	99.8	99.9	100.00

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For the extra-rough jobs

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More ground clearance
Lower center of gravity for better handling and more stability
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For all the details on this improved Traxcavator line, phone your Caterpillar Dealer—same man you call for expert service and replacement parts that don't let you down.

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

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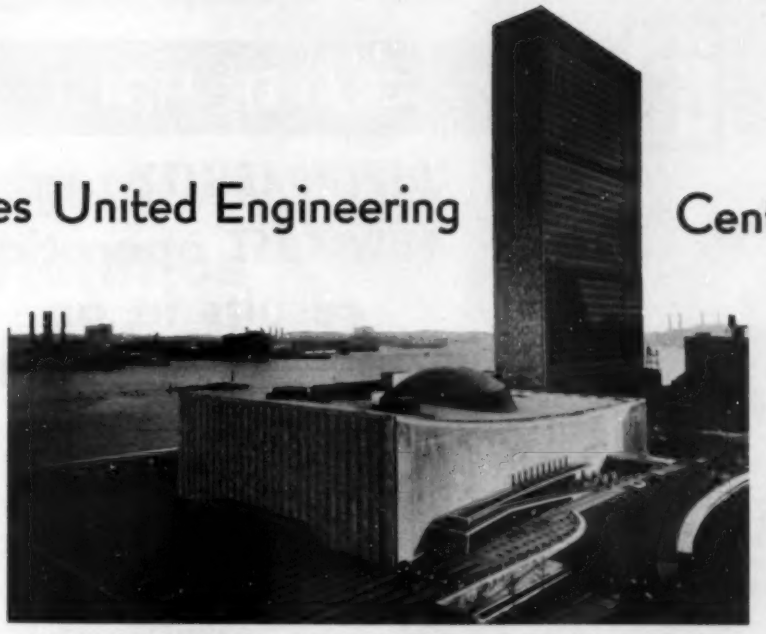
UET Announces United Engineering Center



View of the United Nations headquarters is similar to one that visitors to the future United Engineering Center might see from windows of the yet to be constructed building. The Center will be diagonally northwest of this steel and glass structure.

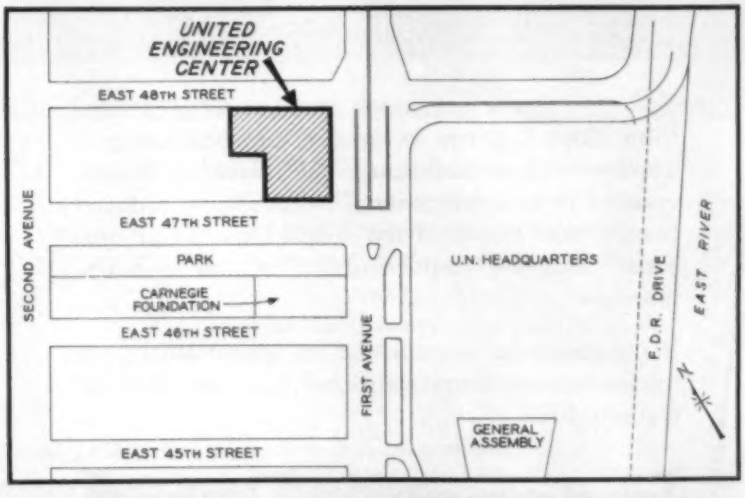
Purchase by the United Engineering Trustees Inc., 29 W. 39th St., of 37,500 sq ft of property on the west side of First Ave. between E. 47th and 48th Sts. at a price of "approximately $2,700,000" was announced July 29th by W. J. Barrett, president of the Trustees.

Mr. Barrett said that the basic purpose of the United Engineering Trustees Inc. is to advance the engineering arts and sciences in all their branches. He added that the purchase of the new site is "the first step in plans which the Trustees are formulating to meet a need for the expansion of the Center's activities."

History of UET

United Engineering Trustees Inc. was established in 1904 and is the corporation in which five national engineering societies (ASCE, AIME, ASME, AIEE, and AIChE) will now be associated in the development of the new property. The five groups represent more than 175,000 engineers in all parts of the world.

For 51 years United Engineering Trustees Inc. has owned and occupied its 16-story Center on W. 39th St. The structure was built in 1906 by a gift of $1,050,000 from the late Andrew Carnegie "to promote the solidarity of the engineering profession."



Sketch shows the location of the site of the new United Engineering Center in relation to adjacent crosstown streets, First and Second Aves., and the United Nations headquarters which lies between First Ave. and the East River in New York. Also visible in the sketch are the park and Carnegie Foundation which lie south of the proposed center.

President Reistle's Report

At the last Annual Meeting President C. E. Reistle, Jr., detailed the steps which had been taken when it became apparent that the existing 39th St. building had become outgrown and outmoded.

His report entitled *A Report on the State of the Institute*, given at the New Orleans Meeting, February 1957, appeared in MINING ENGINEERING, April 1957, p. 422.

President Reistle revealed that the committee responsible for joint planning by the five societies had settled upon New York as the location for the new center, and purchase of a site represents the first concrete step in the development of this project in which AIME will be an active participant.

Location

The newly purchased site includes the entire block front on the west side of First Ave. between 47th and 48th Sts., and extends back from First Ave. for 150 ft on E. 47th St. and for 225 ft on E. 48th St. This section of First Ave. has been renamed the United Nations Plaza.

Title to the principal part of the property was taken by United Engineering Trustees Inc. July 29. Included is the portion owned by the

(Continued on page 1021)

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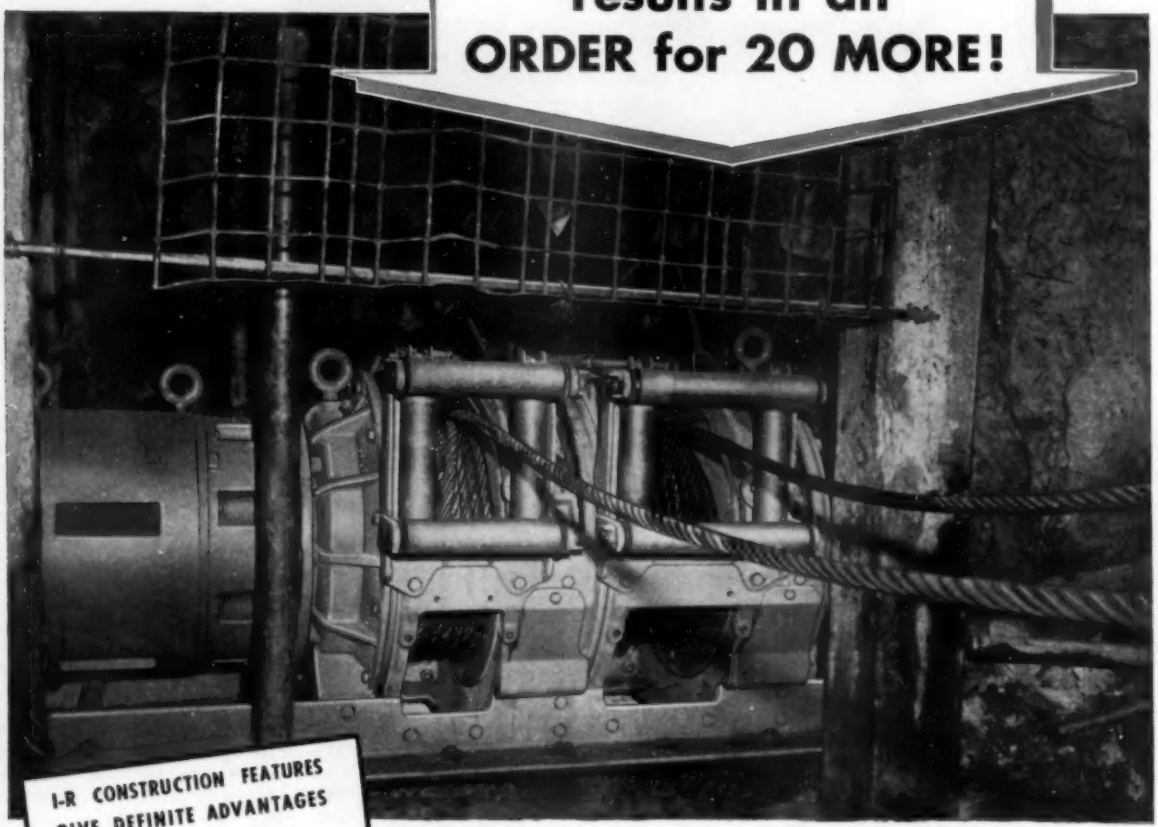

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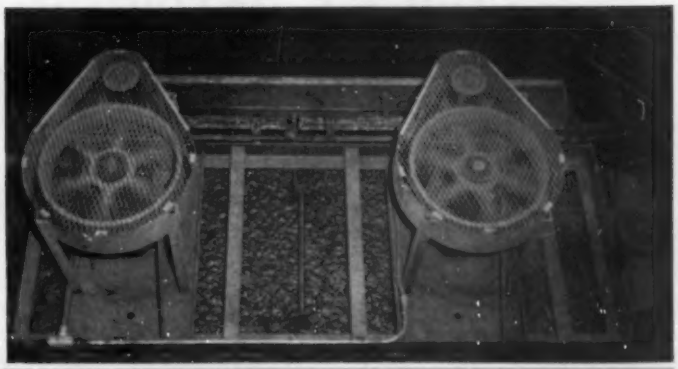

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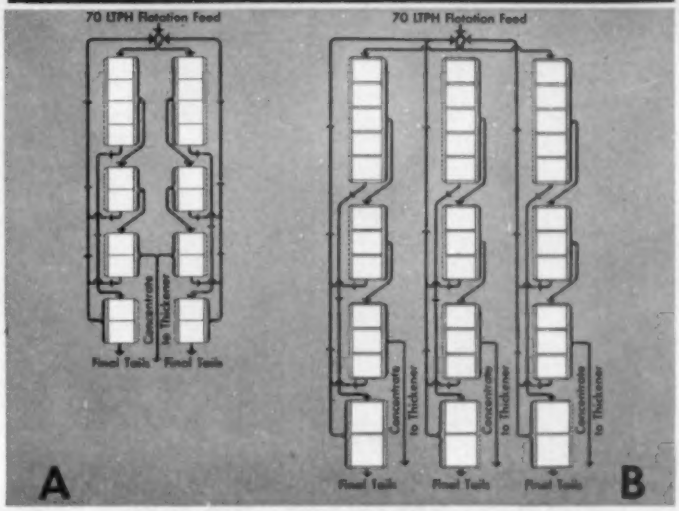
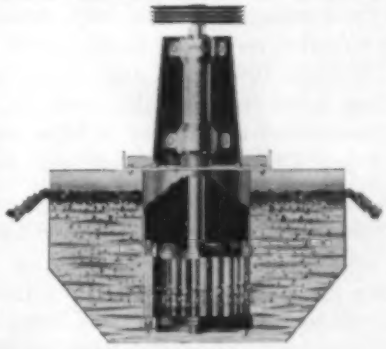


		Wemco Fagergren Units A	Other Flotation Units B
Circuit Characteristics	✓ Number of Cells	20	39
	✓ Gross Cell Volume[1]	1220 cu. ft.	2400 cu. ft.
	✓ Floor space (all cells)	644 sq. ft.	988 sq. ft.
	✓ Launder & Operating aisles (approx.)	167 sq. ft.	261 sq. ft.
	✓ Total Launder Length (approx.)[2]	225 ft.	373 ft.
Typical Metallurgical Results on This Type of Iron	✓ Units of Iron Recovered	1%-2% more	
	✓ Tailings Loss	1%-2% less	
	✓ Reagent Consumption	.2-.3 lbs. less per ton treated	

Notes: 1 – Taggart, Section 12 page 80, shows WEMCO-Fagergren efficiency of cell volume substantially greater than others, in addition to the above noted advantage in space alone.

2 – Shorter launder length in WEMCO circuit allows steeper slope; requires less wash water, causing less dilution of concentrate and minimizing dewatering requirements.



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HOW ST. PATRICK'S COPPER MINE MOVES 1⅓ MILLION TONS OF ROCK A YEAR

ON ITS WAY OUT OF THIS MINE, a huge Caterpillar DW21 Wheel Tractor stops to have its picture taken—for here it is helping to make mining history.

At St. Patrick's Mine near the village of Avoca in County Wicklow, Ireland, four 30-ton units are operating *underground*—first machines of their size ever to do so, anywhere in the world.

The machines are CAT* DW21s (Series C). They're hauling earth and rock from inside the mine tunnel to an outside dumping area. The tunnel is 17 ft. high, 16 ft. wide, and when it is finished it will run 8,000 ft. at an 11% slope. In and out of this tunnel roll the mighty DW21s, each hauling an Athey PR21 rubber-tired rear dump trailer with 34-ton load.

When the haulage-way is completed, St. Patrick's will work three ore bodies—which are at different levels—in one 20-year program. 1⅓ million tons of rock will come out of the ground here each year, on the fast-moving wheels of St. Patrick's 300 HP (maximum output) Caterpillar DW21 Wheel Tractors.

How are the DW21s doing on this history-making assignment? "They are easy to handle," reports transport foreman Phelim Doyle. "I would like to have ten more." Operator Thomas Doyle agrees: "It's easy to steer, and it has plenty of power."

Your Caterpillar Dealer will give you complete information on this remarkable unit. For example, special exhaust scrubbers are available for the DW21's engine for underground work. Ask him about its performance on any kind of stripping or hauling job. Call on him, too, for expert service—and for replacement parts you can trust.

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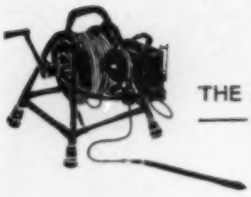

Columnar Ion Exchange — Resin-in-Pulp — Solvent Extraction

by

the Staff of the Colorado School of Mines

Research Foundation Inc.

URANIUM is commonly recovered by either column ion exchange (IX) or basket ion exchange (RIP) from solutions resulting from sulfuric acid leaching of uranium-bearing ores. In both operations a solid state ion exchanging resin is used, the major difference being that practically clear uranium pregnant solutions are required for passage through resin columns whereas in RIP, leach slurries from which only the sands have been removed are caused to flow through ion exchanging resins contained in baskets. The solvent extraction process as used for recovering uranium from acid leach solutions is also an ion exchanging process, but one in which the ion exchanging medium is a liquid rather than a solid state resin. For this reason, SX is often referred to as *liquid ion exchange*, although *liquid-liquid extraction* is probably more accurate.

Uranium in its sulfuric acid leach solutions exists in an equilibrium that may be visualized as follows:

$$\begin{matrix} -4 & & -2 & & 0 \\ [UO_2(SO_4)_3] & \leftrightarrows & [UO_2(SO_4)_2] & \leftrightarrows & [UO_2(SO_4)] \\ +2 & & -1 & & -2 \\ \leftrightarrows (UO_2) & \leftrightarrows & (HSO_4) & \leftrightarrows & (SO_4) \end{matrix}$$

Because of an equilibrium of this nature, uranium may be recovered on either cation exchanging or anion exchanging resins and then concentrated during the resin eluting operation. Similarly, solvent extraction processes may utilize either anion exchanging or cation exchanging liquid organic phases, which capture the uranium and permit its subsequent concentration when the organic phase is stripped.

Popular cation exchanging solvent extraction reagents are represented by a class of organo-phosphates, of which di-2-ethyl-hexyl phosphoric acid is typical. Anion exchanging reagents comprise a group of long-chain amines. These water-immiscible reagents are dissolved in kerosene or other low cost hydrocarbon to yield the corresponding *resin phase* of the SX process.

The solvent extraction process has all the advantages of a completely liquid operation and in this respect contrasts sharply with IX or RIP, which must provide for a solid state resin. Based on the relatively limited experience of the uranium milling industry with the SX process, thus far reported, advantages of SX as compared with IX and RIP are: 1) greater versatility; 2) less sensitivity to solution impurities; 3) greater ease of process control; 4) lower reagent inventory; and 5) smaller space requirements. On the other hand, SX is at a relative disadvantage due to loss of expensive organo-phosphate or amine reagents as the result of their water entrainment, water solubility, and mechanical spillage. In addition, the problem of emulsion difficulties in SX operations has not yet been completely resolved. It may also be noted that in SX, when amine reagents are used, uranium pregnant head solutions must be practically clear, although organo-phosphate systems are reported to tolerate up to 300 ppm suspended solids without serious difficulty.

It is considered premature to attempt an evaluation of the relative economics of SX as compared with IX and RIP in the uranium milling industry. Present high interest in SX dates only from mid-1955, and although several Plateau mills using resin ion exchange have also installed SX circuits and some mills under construction will use SX only, operating data on the SX process is still meager.

The long-range potential of the SX process may well revolve around the ability of this process to accommodate precipitation and solution purification simultaneously with the stripping of uranium from the loaded organic and regeneration of the organic reagent for recycle. This operational combination is not possible, of course, during the corresponding elution step of the solid state resin. In one present application, a sodium carbonate solution is used to strip an organo-phosphate kerosene system, thus precipitating heavy metals while maintaining the uranium soluble in the aqueous concentrate. Selective precipitation of uranium and vanadium from the loaded organic phase is also possible, and considerable developmental work is now under way on the direct precipitation of UF_4 from SX circuits.

THE SEARCH FOR LOWER COSTS
— PROBING THE PROCESSES

Recent Trends in Extracting Uranium

by Frederick B. Brien

DEVELOPMENT of uranium extraction techniques over the past ten years has been spectacular. Rapid progress has been made by applying chemical, physical, and engineering fundamentals for the purpose of devising simpler processes, developing continuous procedures, reducing reagent consumption, improving final products, simplifying analytical methods, and treating more refractory ores and ores of lower grade. Since the source of many valuable metals in future will be of necessity from lower grade ores of a complex nature, and since hydrometallurgical processes are often the only means of treating such materials, these recently developed techniques will be of increasing importance.

Leaching: A great deal has been published about the important role of ion exchange resins in purifying and concentrating leach solutions. Recent applications indicate that the resins will be very useful in simplifying leaching procedures of ores containing two or more valuable metals.[1] The valuable metals may be differentially adsorbed by careful control of the oxidation-reduction potential of the pregnant liquors. For example, treatment of vanadium-uranium ores at present may involve salt roasting, water leaching, acid leaching, carbonate leaching, and intermediate fusions. Use of a single acid leach may now be possible, followed by a two-stage ion exchange technique, comprising initial adsorption of hexavalent uranium and rejection of tetravalent vanadium. The solution is then oxidized, producing pentavalent vanadium, which is later readily adsorbed and stripped into a separate eluate.

An interesting development is the use of high pressure leaching, at elevated temperatures, on pyritic uranium ores, in which the required acid is generated from the contained sulfide.[2] This technique had previously been tested experimentally on pyritic ores for producing elemental sulfur, iron oxide, and sulfuric acid and on copper-nickel ores for producing elemental sulfur, iron oxide, and a sulfate solution of copper and nickel. In the process an increased partial-pressure of oxygen is maintained with increased temperature, which produces enough sulfuric acid from the pyrite to dissolve the uranium. It may prove profitable to add the pyrite if a cheap source of supply is available. This technique may be of particular importance where reagent costs are high and minerals are refractory at normal temperatures and pressures.

Carbonate leaching is generally carried out on high lime ores, using sodium carbonate and sodium bicarbonate. Tests have indicated that the use of ammonium carbonate and ammonium bicarbonate, in a closed system, may have advantages due to ease of recovery and regeneration of the solvent.[3] The uranium may be precipitated by steam stripping, during which time ammonia and carbon dioxide are absorbed by the filtrates, which are carbonated to a further degree and recirculated.

Another process that has been attracting considerable attention in research laboratories recently is "extraction in non-aqueous solutions."[1] This is an attempt to solubilize uranium minerals by use of an acid cure followed by direct adsorption into an organic solution, for example, 2 to 5 pct of an organophosphate in acetone. Results have indicated that some ores in which the uranium is in the hexavalent form may be dry ground and pugged with relatively small amounts of acid and the values extracted. This procedure suggests elimination of several solid-solution separations, reduced reagent consumptions, and production of a high grade final product. Ores that require oxidation prior to extraction have been pugged with nitric acid, aqueous chlorine, or bromine with effective results. Testing is being carried out to devise means of simplifying the separation of organic and solid with reduced entrained losses.

In Yugoslavia carbonate leach solutions from low grade ores are recycled five to ten times to build up concentration and thus reduce precipitate handling and conserve reagents. A single wash is used on each filtration step, resulting in a soluble loss of 1 to 2 pct. Uraniferous coal ashes are used as leach feed in this country also, assaying 0.015 to 0.05 pct U_3O_8.[4]

In South Africa, where oxidizing reagents are a costly reagent item, the MnO_2 is recovered from ion exchange effluent with lime after first selectively precipitating the contained iron.[4] The manganese hydroxide is calcined and the product used again.

F. B. BRIEN is Associate Professor of Mineral Engineering, University of Washington, Seattle.

Solution Purification and Concentration-Precipitation: In the application of ion exchange resins for purification and concentration, research has been striving to develop more simplified techniques. Resin-in-pulp procedures, while eliminating difficult solid-solution separations and simplifying process control relative to ion exchange columns, has presented the problem of costly equipment maintenance. Continuous ion exchange equipment has been designed utilizing rake classifier mechanisms and fluidized beds with countercurrent flow for continuous resin circulation.

Tests have indicated that ion exchange resins have an application to carbonate leach solutions also. Although carbonate leaching has had the property of being highly selective to uranium in its applications, the use of ion exchange for concentration purposes will reduce the solution volumes handled in precipitation and reduce reagent consumptions.

Char-in-pulp techniques have been greatly improved by using char that has been activated by an organic compound, which is adsorbed by the charcoal and will itself selectively adsorb uranium.[6] The process is a compact operation, as the char can be separated from the pulp by simple screening. A high degree of selectivity has been indicated, resulting in a high grade product. A typical activating reagent used in testing is dioctylpyrophosphoric acid.

Solvent extraction has been proved in pilot plant testing and designed into at least three plants. The present technique involves extraction of values from the filtered pregnant solution. Research is being carried out to determine the economics of using solvent extraction directly in the leach pulps, thus simplifying the procedure by eliminating solid-solution separations.[6] Solvent extraction has shown advantages over ion exchange—a continuous process, simplified plant control, lower capital costs. To reduce precipitation costs and to produce a highly concentrated final solution and higher grade products, some thought has been given to using a small solvent extraction plant in conjunction with present ion exchange installations.

The use of electrolytic precipitation of uranium using ion exchange membranes has indicated favorable results in small-scale tests.[7] Low power and plant installation costs are possible. The process allows recovery of the acid eluant, with very small reagent consumptions, and produces high grade granular precipitates.

Analytical Processes: A great deal of research is being carried out to devise simpler and more accurate uranium analyses. Various methods are used for high grade precipitates, low grade tailings, and high and low grade plant solutions.[8] Test work has indicated that paper chromotology,[9] used in medical and biological analytical laboratories for many years, has met with some success for a more rapid evaluation of plant solutions.

Recent testing has indicated that the polarograph can be used for uranium determinations over a wide range of concentrations without preliminary chemical separation.[10]

Use of the spectrophotometer in recent years has increased accuracy and simplified procedures for determining uranium content of solution.[11]

Procedures have been devised for using small ion exchange columns for analytical purposes.[12] Results have indicated that the technique may prove very useful for rapid routine methods.

Preconcentration: Use of flotation on North American ores for producing high grade products with acceptable recoveries has not been successful, particularly on the fine sizes. However, flotation testing is applied to uranium ores for the purpose of: 1) reducing the carbonate content of an ore prior to acid leaching; 2) producing a carbonate leach feed and an acid leach feed from an ore that gives poor selectivity in a carbonate flotation operation; 3) obtaining a pyrite concentrate from the ore for production of sulfuric acid.[9] In France excellent results have been claimed for the flotation of parsonite (uranium-lead phosphate) with oleic acid in alcohol, returning up to 90 pct recovery at a concentration ratio of 60 from a low grade ore.[10]

Sink and float testing has encountered difficulty in producing a satisfactory waste product, due mainly to incomplete liberation of valuable mineral at sizes dictated by plant size equipment. However, research work using a heavy media in cyclones has indicated excellent results on fine sizes when short range feed materials are used.

Differential attrition grinding, either wet or dry, has given satisfactory results on some very low grade ores and has recently been incorporated in a plant of commercial size. New flocculating agents have improved handling characteristics of such products.

The La Point pecking belt, which has been made more sensitive by scintillator scanners, has been found useful for sorting radioactive ores in the coarse size ranges (8 to 1½ in.) on a laboratory scale.[14]

Summary

A great deal of research has been carried out over the past few years to improve and simplify uranium extraction processes. Important contributions have been made to knowledge of the physical chemistry and thermodynamics of hydrometallurgical operations; improved filters, agitators, corrosion-resistant materials, and pumps have been developed; and knowledge has been increased concerning the mechanics of mixing, residue washing, agitation, control of diffusion, and other reaction rate limiting processes. However, as in most fields of technology, the more that is learned, the more variables are revealed that require investigation. With present incentives in the metals extraction field there will be many more improvements and changes in flowsheets as knowledge is gained. New plants going into production with their process and control research laboratories can be expected to contribute materially to further simplification of hydrometallurgical techniques. The effect present knowledge will have on the treatment of other valuable metals—cobalt, nickel, aluminum, magnesium, tungsten, manganese, and copper—can only be imagined.

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THE SEARCH FOR LOWER COSTS
— PROBING THE PROCESSES

Innovations in Processing Uranium Ores

by J. B. Rosenbaum

W. L. Lennemann

J. B. Clemmer

Security restrictions on processing uranium raw materials to yellow cake were lifted in August 1955, coincidental with the Geneva Conference on Peaceful Uses of Atomic Energy. Numerous reports and technical papers on uranium extraction and recovery methods have appeared since that time, and it is doubtful that another review of past and current practices would add much to the technical literature. Development of some promising procedures was arrested, perhaps temporarily, by mechanical handling problems or peculiarities in the chemistry of uranium and associated elements. Some methods have been incompletely evaluated and still others that tested well in the laboratory and pilot plant are dormant because of competition from other processes, or because of their restricted applicability to particular ore types that have not reached quantity production. In view of the vast number of new ideas and procedures that have been advanced, considered, and tested, it would be futile to attempt a comprehensive survey in this article. Only a cross section of the field, based on random sampling, can be provided here. The authors have chosen, therefore, to discuss some innovations that may provide a clue to uranium ore processing techniques of the future. An effort has been made to select unpublicized new metallurgical techniques or interesting applications of established principles and procedures. With the two exceptions noted later, all the research to be described has been sponsored by the AEC.

Physical Beneficiation: Individuals and firms engaged in mining and processing uranium ores, and in related research activities, have often had considerable experience in ore dressing. As might be expected, therefore, a prodigious amount of work has been done on physical beneficiation testing of uranium ores, particularly in efforts to concentrate subgrade materials. Although some success has been attained on specific ores by gravity concentration and flotation, ratios of concentration have generally been low and there has been difficulty in making a throwaway tailing.

The frequent occurrence of uranium mineralization as incrustations in fracture planes and as soft, pulverulent coatings on sand grains long ago suggested the possibility of scuffing the ore to abrade the uranium minerals without breaking the relatively harder gangue particles. This selective grinding, commonly referred to as *attrition grinding*, can be done wet or dry. The fine fraction obtained by size classification of the ground material is enriched in uranium. The basic considerations and mechanisms for attrition grinding of carnotite ores were given in a USBM bulletin published in 1913.[1] Examples are recorded in which Colorado Plateau carnotite ores that assayed 2 pct U_3O_8 were upgraded to between 4 and 8 pct U_3O_8 with a 50 pct recovery. The unusual emphasis on grade at that time is explained by the fact that the concentrates were shipped to Europe for processing.

More recent work at the Intermountain Experiment Station has been focused on ores assaying about 0.1 pct U_3O_8. Methods employed included wet scuffing followed by fractionation in classifiers and cyclones and drying attritioning in a laboratory disintegrator followed by air classification. Recovery of 70 to 80 pct of the uranium in concentrates assaying 0.2 to 0.4 pct U_3O_8 was obtained from the amenable ores. Wet and dry procedures gave about the same results. Power requirements were lower in wet attritioning and sizing, but wet methods entail a solids-liquid separation step employing a flocculant to accelerate thickening and filtration of the slime concentrate.

Vanadium Corp. of America in Monument Valley employs a simple attrition procedure for mechan-

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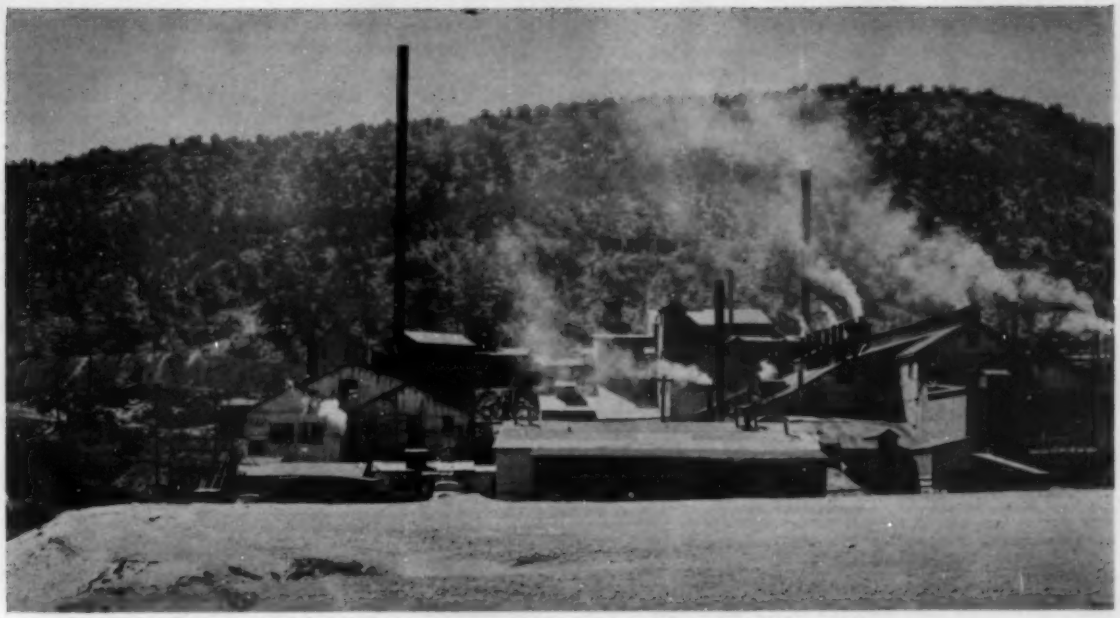


Vanadium Corp. of America's plant located at Naturita, Colo.

ical upgrading of uranium ores.[2] Ore assaying 0.05 to 0.10 pct U_3O_8 is lightly ground in a rod mill and fractionated into sand and slime by a spiral classifier. Slime entrained in the classifier sands is scalped out in a cyclone and returned to the classifier. Sand discharge from the cyclone is discarded. The enriched slimes from the classifier are thickened, with a flocculating agent to accelerate the settling rate, then filtered and dried. About 60 to 70 pct of the uranium is recovered in a product assaying 0.25 to 0.30 pct U_3O_8, which becomes part of the feed to VCA's Durango plant.

A serious drawback to concentration of uranium ores by attrition grinding is that the slime concentrate presents special handling problems in conventional acid or carbonate leaching processes. These problems are minimized by salt roasting, which improves settling and filtering of the slimes.

Good results were attained by the USBM station in Tucson in floating a carbonaceous uranium concentrate from asphaltic ores of the Temple Mountain district in Utah. The tailing assay was comparable to that obtained by conventional acid leaching, but the ratio of concentration was only 4 to 1. Since the flotation concentrate must still be burned and the calcine leached with acid, no clear-cut economic advantage was established for the preflotation step.

Similar results were obtained on low-lime sandstone ores containing carnotite, autunite, torbernite, or uranophane as the principal uranium mineral. Flotation of uranium from the finely ground ores with a fatty acid collector gave a severalfold enriched concentrate, but a throwaway tailing was difficult to make because of uranium losses in the slime. Further improvement in flotation of such ores depends on development of a more effective and specific collector for slimed uranium minerals.

Considerable research has been done to develop a method for selective flotation of calcareous ores of the Lukachukai district assaying about 0.20 pct U_3O_8 and 10 to 12 pct $CaCO_3$. Batch flotation tests were supplemented by continuous runs in a 100-lb per hr pilot plant at the Intermountain Experiment Station. The continuous test unit was operated around the clock for several weeks. The ore was ground in a rod mill to 100 mesh and floated to recover the small amount of uranium-bearing carbonaceous material, which was subsequently combined with the uranium concentrate. The calcite was then floated and double-cleaned to give a calcite concentrate. The calcite rougher and cleaner tailings comprised the feed for uranium flotation. A typical single-shift run showed that 78 pct of the uranium could be recovered in a concentrate that represented 27 pct of the weight and assayed 0.6 pct U_3O_8 and 11 pct $CaCO_3$. The calcite product represented 13 pct of the weight and assayed 0.3 pct U_3O_8 and 57 pct $CaCO_3$. About 18 pct of the uranium and 72 pct of the lime reported in the calcite product. The throwaway tailing assayed 0.015 pct U_3O_8 and less than 1 pct $CaCO_3$. The continuous tests made with raw or reclaimed water showed that a partial separation of carnotite from calcite could be made in an upgraded product while making a throwaway tailing, but results were not attractive enough to justify the complicated flowsheet.

The alternative purchasing schedule now being used at some uranium ore buying stations, whereby the seller can elect waiver of the lime penalty in lieu of payment for vanadium, may be expected to increase deliveries of high-lime ores that will heighten interest in lime flotation studies. Calcium carbonate, usually called lime in uranium industry parlance, is a deleterious constituent in uranium ores treated by salt roasting or acid leaching. In the salt roast process used for vanadium-uranium ores, the calcite results in high vanadium and uranium losses. The objection to calcite as an acid consumer in acid processing needs no elaboration. Selective removal of lime by flotation appears to offer a ready solution to the lime problem in certain ores.

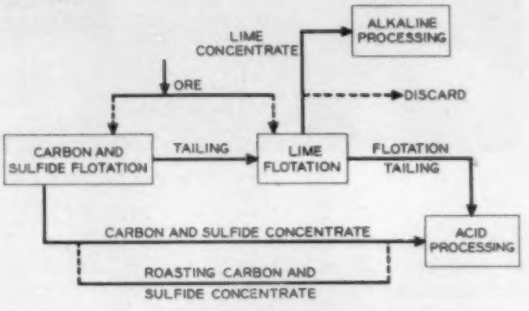
Flotation of a throwaway lime concentrate has not been successful. Batch and small-scale continuous flotation tests have shown that the best that

could be expected from a feed assaying 15 pct $CaCO_3$ and 0.28 pct U_3O_8 would be a lime concentrate assaying 80 pct $CaCO_3$ and 0.10 pct U_3O_8. About 65 pct of the lime could be rejected with a loss of 6 pct of the uranium. A lower uranium-lime concentrate was made in some tests, but only at the expense of lime rejection.

The success enjoyed by carbonate leach plants working on high-lime uranium ores and the development of enough ore supplies to warrant both acid and alkaline units in an integrated plant suggest the possibility of splitting the ore into a low-lime fraction for acid leaching and a high-lime fraction for treatment in an alkaline circuit.

Splitting the lime ores into high and low-lime fractions without regard for uranium distribution presents no particular problem. Tests on Big Indian Wash ores, assaying 13 to 38 pct $CaCO_3$, demonstrated that nearly 95 pct of the lime could be floated into a concentrate containing about 30 pct of the uranium in the ore. The tailing contained only 1 to 2 pct $CaCO_3$. Laboratory tests showed that these flotation products responded well to respective carbonate and acid leaching. Incidental oxidation during flotation processing appears to have a beneficial effect on the subsequent carbonate leach of the calcite concentrate. A prefloat to remove carbonaceous matter and sulfides, which often contain a disproportionately high percentage of the uranium, is a logical accessory to lime flotation and offers the possibility of separate treatment for refractory components of the ore. Testing has established that the flotation reagents are not harmful in subsequent processing of the flotation products, with regard particularly to fouling of ion exchange resins. Some questions do remain on the effect of the flotation reagents building up in a closed carbonate leaching circuit.

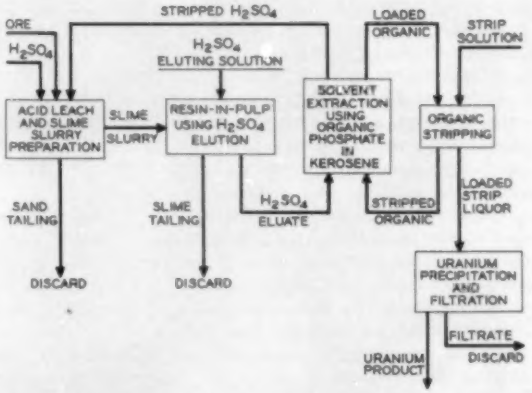
When vanadium recovery is not a consideration, the premises for justifying selective flotation of lime are that better uranium extraction or lower costs can be achieved by processing a part or all of the ore in an acid circuit than by treating all the ore in an alkaline circuit. As alkaline leaching works well on the majority of ores containing 10 to 25 pct lime, close figuring would be needed in most instances to establish an advantage for lime flotation. Exceptions are recognized in plants already committed to an acid circuit or in plants where flotation of a throwaway calcite concentrate might prove to be practicable.



Solvent Extraction of Sulfuric Acid Eluate

Solvent Extraction of Sulfuric Acid Eluate: Ion exchange processes for recovering uranium from acid-leach solutions or pulps are based on selective adsorption of an uranyl anion complex with subsequent elution using a mineral acid or an acidified salt solution. The elution step removes the uranium and regenerates the resin for the adsorption cycle. Uranium is recovered from the eluate by neutralizing with ammonia, caustic soda, or magnesium oxide. Precipitation of uranium from an ion exchange eluate, assaying from 7 g to as high as 15 g per liter U_3O_8, involves handling large quantities of solution. The cost of chemicals for elution and precipitation is an important item. Even though part of the barren eluate may be recycled in some systems, it may be problematical to dispose of the remainder of the eluate in accordance with the pollution regulations. Re-extraction of the ion exchange eluates with an organic solvent was examined in small-scale continuous test units at the Intermountain Experiment Station and appeared to offer an advantage in reagent cost over direct precipitation of the eluate. Another advantage was that a lower grade eluate would be acceptable and hence less ion exchange equipment would be needed. This exploratory work was later expanded into a more comprehensive investigation at the Winchester laboratory.

The loaded resin is eluted with 1 molar sulfuric acid and the eluate, assaying about 7 g per liter U_3O_8, is re-extracted with an organic phosphate in kerosene. The sulfuric acid raffinate, which contains about 0.2 g per liter U_3O_8, is returned to the



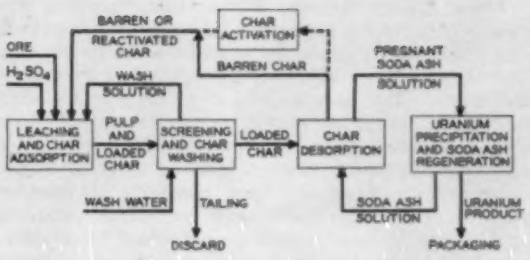
ore leaching step to utilize the acid fully and recover the residual uranium. Complete removal of uranium from the eluate is unnecessary in the combination process. The loaded organic is stripped with acid or carbonate solution to give a barren organic for recycle. A final uranium product is obtained by precipitation of the loaded strip liquor assaying 65 g per liter or more in uranium.

With this process savings in the ion exchange plant are possible owing to the acceptability of lower eluate loading, eluate disposal problems are minimized, and a final uranium product of higher purity can be attained at a lower reagent cost. Disadvantages are the corrosive action of the acid solution and complexity of the flowsheet.

Char-In-Pulp

Char-in-Pulp: The char-in-pulp system, developed by Arthur D. Little Co., embodies essential features of both resin-in-pulp and solvent extraction of slurries. The procedure is similar to the char adsorption process used by the Golden Cycle Corp. at Victor, Colo., to recover gold from cyanide leach pulps. The difference is that char selectivity adsorbs the gold complex, whereas in the uranium process it serves as a carrier for dioctyl pyrophosphoric acid (OPPA), or a similar organic phosphate, that extracts the uranyl cation. The loaded char is screened from the barren pulp and stripped of uranium by countercurrent contacting with a soda ash solution. The char after stripping is recycled to the adsorption step. Uranium is recovered from the soda ash strip solution by neutralization or caustic precipitation, the barren strip liquor being regenerated and recycled. Because of silica poisoning, periodic reactivation of the char may be necessary.

A potential advantage of the char-in-pulp over the conventional resin-in-pulp procedure is that it



should be possible to combine leaching and adsorption in a single operation and thus avoid a sand-slime separation. An advantage over solvent extraction of leach slurry is that organic entrainment losses are minimized. More research may overcome the disadvantages of organic phosphate loss due to solubility in the aqueous phase, incomplete uranium extraction, and the large quantity of char that must be handled because of low uranium loadings.

Pressure Oxidation Leaching

Pressure Oxidation Leaching: To take advantage of the presence of sulfide minerals in some uranium ores the Canadians and Australians, in particular, have examined pressure oxidation leaching. The aqueous pulp of the ore is treated with air or oxygen at elevated temperature and pressure, thereby oxidizing the sulfide minerals to produce the acid needed for dissolving the uranium minerals. An article by Forward and Halpern[4] has described the conditions and controls employed. General conditions for extracting 90 to 95 pct of the uranium from ores assaying 0.1 to 0.6 pct U_3O_8 and 1 to 13 pct sulfur were given as 4 to 6 hr leaching at 130°C and an oxygen partial pressure of 10 psi. The feed was ground to about 60 pct −200 mesh and leached at 65 pct pulp solids.

The principal advantage of autogenous leaching appears to be acid generation. Presumably, if not enough sulfides are present, pyrite or sulfur could be added to supply the acid required for leaching. Also, ores that are refractory to atmospheric leaching may respond better to the more rigorous conditions of the pressure leach. Disadvantages are the higher capital and maintenance costs of pressure equipment. So far as known, only laboratory work has been done on the process. Experience with pressure oxidation leaching of cobalt concentrates at Calera's Garfield refinery, under more severe conditions than contemplated for uranium ores, may be a guide to the practicability of pressure oxidation leaching of uranium ores on an industrial scale.

Hydrogen Precipitation of Uranium from Soda Ash Solution

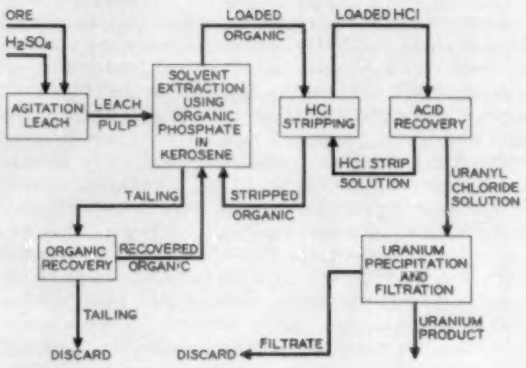
Hydrogen Precipitation of Uranium from Soda Ash Solution: Uranium is normally recovered from soda ash solution by addition of excess caustic soda to precipitate sodium diuranate. After the precipitate is filtered, the filtrate is carbonated with flue gas to convert the excess caustic to sodium carbonate and bicarbonate for recycling to the leach. Since vanadium is not precipitated, it builds up with progressive recycling of the leach solution. Uranium precipitation is incomplete if the solution contains more than 2 or 3 g per liter of vanadium, and therefore solutions high in vanadium require another processing step to remove the vanadium as ferrous or as lead vanadate prior to caustic precipitation of the uranium.

Considerable research has been done on the use of hydrogen gas to recover uranium from pregnant carbonate solutions. Reduction is carried out at 100° to 150° C under a hydrogen partial pressure of 50 to 200 psi. The reaction is catalyzed by nickel powder or shot and the rate of reaction can be controlled by the amount and form of the catalyst. The initial work employing nickel powder catalyst was done and reported by F. A. Forward and J. Halpern of the University of British Columbia.[5] Subsequent work by National Lead Co. Inc. at the Winchester laboratory of the AEC developed the nickel shot catalyst, which is more easily separated from the uranium precipitate than the powder catalyst. The hydrogen reduction procedure gives a low-uranium barren solution regardless of the vanadium content of the leach solution. Unfortunately, however, the vanadium coprecipitates with the uranium.

The pressure hydrogen reduction procedure has an advantage over caustic precipitation in that vanadium does not interfere with precipitation of uranium, and the solution for recycle is free of uranium and vanadium. It has been regenerated and needs only makeup addition of the soda ash consumed in the leach. It has the disadvantages of requiring pressure equipment; a nickel catalyst that must be separated from the precipitate; and hydrogen, which is less readily available than flue gas used in caustic precipitation. Also there is an explosion hazard. The method is unattractive for high-vanadium ores, as the precipitate must be reprocessed to separate uranium and vanadium.

Thick Slurry Solvent Extraction

Thick Slurry Solvent Extraction: Provided organic entrainment losses can be suitably controlled, extraction of uranium by organic solvents from a thick leach slurry offers an ultimate in process simplification. The process was developed at the Salt Lake City station as an offshoot of the research on clear liquor and slime slurry solvent extraction.[6] Ore ground to about 35 mesh is leached at 40 to 60 pct solids with sulfuric acid in a conventional manner with or without an oxidant as needed. A reducing agent such as iron powder or sodium thiosulfate may be added to the final leach tank to reduce ferric iron to the ferrous form and thereby minimize iron contamination in the final product. The thick leach slurry at a pH of 1.0 or less is then contacted countercurrently with a dilute solution of dodecyl phosphoric acid in kerosene. Internal mixer contactors, which combine mixing and phase separation in the same apparatus, are used for the extraction and stripping steps. Barren leach slurry is treated for solvent recovery, if necessary, before being discarded. The loaded organic is stripped by countercurrent contacting with hydrochloric acid, and the regenerated organic is recycled to extraction. Loaded acid strip liquor assaying about 60 g per liter U_3O_8 is concentrated to 350 g per liter U_3O_8 by evaporation, and 70 to 80 pct of the hydrochloric acid is recovered for re-use in the stripping step. An ammonium diuranate product is obtained by treating the concentrated uranyl chloride solution with ammonia.



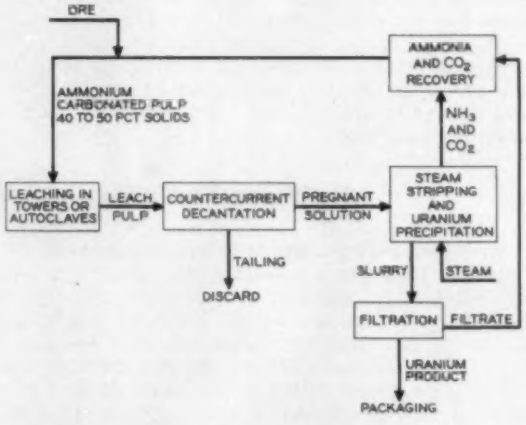
Advantages over clear liquor or slime slurry recovery procedures are that fewer steps and less equipment are needed. The method has an advantage over the nonaqueous procedures in that conventional agitation leaching can be used rather than acid curing, which does not always give good uranium extraction and has proved expensive in terms of labor and reagents. The salient disadvantage of thick slurry extraction is that a practicable method for keeping organic entrainment losses within acceptable limits has not yet been devised. Research on thick slurry extraction has been attractive enough to warrant a continuation of the work.

Ammonium Carbonate Leaching

Ammonium Carbonate Leaching: Alkaline processing of uranium ores has several advantages over acid treatment because of the inherent selectivity of the alkaline solution for uranium, the bland nature of the lixiviant which makes it unnecessary to use expensive corrosion-resistant construction materials, and the relative ease of recovering the uranium from solution and regenerating the leach liquor.

The alkaline solution used currently by industry for carbonate leaching contains 5 to 10 pct sodium carbonate and 1 to 2 pct sodium bicarbonate. Work also has been done on uranium precipitation and solution regeneration using such processes as diaphragm electrolysis, mercury cathode reduction, and ion exchange. If ammonium carbonate is used in place of sodium carbonate for leaching, the uranium can be recovered by sweeping the solution with steam to reduce the ammonium carbonate concentration and precipitate uranium oxide with the ammonia being recovered for re-use.

Research work has been done by Battelle Memorial Institute to develop an ammonium carbonate leaching process incorporating this attractive recovery and regeneration procedure. Ore ground to —100 mesh is leached in towers or autoclaves at 50 pct solids in a solution containing 100 g of ammonium carbonate and 20 g ammonium bicarbonate per liter. Whether leaching is done at elevated or atmospheric pressure, a closed system must be used to prevent loss of ammonia. The pregnant solution is separated from the leach residue by countercurrent decantation. Uranium hydrates, precipitated by steam-stripping the pregnant solution,



are recovered by filtration. The ammonia and part of the CO_2 in the gas from steam stripping are absorbed in the filtrate, and the solution is further carbonated with flue gas for recycling to the leaching step.

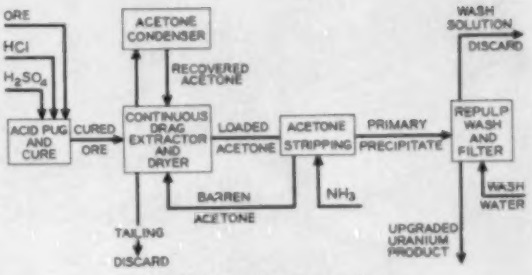
The principal advantage of the ammonium carbonate process over conventional soda ash leaching appears to be ease of precipitation and potential reagent savings. The main disadvantage is that a gas-tight system must be maintained to prevent ammonia loss. Further studies of the process at the Winchester laboratory by National Lead Co. revealed uranium extraction problems when the ores contain vanadium.

Nonaqueous Extraction: The development of vegetable gums and synthetic flocculants to accelerate thickening and filtering of leach pulps has greatly improved liquid-solid separations in uranium ore processes.[5] Even so, either countercurrent decantation or filtration involves capital and operating expenditures the operator would like to avoid. Considerable research has been devoted to nonaqueous extraction methods in the hope of shortcutting the recovery routine.

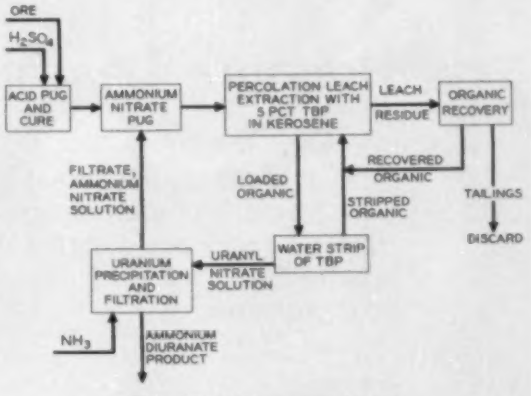
Selective leaching of uranium from ores by nonaqueous reagents has not shown much promise, but by treating the ores with mineral acids in the presence of very little water, it is possible to convert the uranium to forms that are extractable by nonaqueous solvents. Two so-called nonaqueous systems will be described here, both using about 10 pct water on an ore weight basis.

Work on the acetone-chloride extraction process was done at Battelle. In this procedure, ore crushed to 10-mesh is pugged with hydrochloric and sulfuric acids for curing to solubilize the uranium. The cured material is fed continuously into a pool of acetone in an enclosed drag-type extractor. The uranium, iron, vanadium, calcium, and other metallic ions are absorbed as chloride complexes by the acetone that overflows the extractor. The leach residue, which settles very rapidly, is dragged over a heated drying section at the upper end of the extractor, where entrained acetone is volatilized. The acetone vapor is condensed for return to the extractor pool. The loaded acetone is gassed with anhydrous ammonia, which precipitates the uranium, iron, vanadium, and calcium hydroxides. These are removed by filtration, and regenerated acetone is returned to the drag extractor. The final concentrate after washing is low grade and contains 10 to 15 pct U_3O_8, depending on the concentration of impurities. Since acetone is not selective for uranium chloride over other metallic chlorides the process is primarily suited to upgrading. Advantages of the system are that little water is necessary, overall reagent requirements are not excessive, and a relatively small installation might be practicable for upgrading ores in an isolated location. Disadvantages are that both hydrochloric and sulfuric acids are needed, corrosion problems are likely to be severe, the system must be gas-tight to minimize acetone losses, and the precipitated hydroxides are bulky and low grade.

Another nonaqueous extraction process was developed by National Lead Co. at the Winchester, Mass., laboratory of the AEC. This procedure uses tributyl (TBP) to extract uranyl nitrate and gives a high grade uranium concentrate. The ore is crushed to −10 mesh and pugged with sulfuric acid and a little water. After an hour or so of



Acetone-Chloride Nonaqueous Process



TBP—Nitrate Nonaqueous Process

curing to dissolve the uranium, the pugged material is wetted with an ammonium nitrate solution and the damp mass is leached on a moving belt by percolation with 5 pct TBP dissolved in kerosene. The leach residue is washed with a volatile organic solvent to recover the entrained TBP for return to the system. The loaded organic phosphate from the percolation leach is stripped with water to give an uranyl nitrate solution for precipitation with ammonia. After filtration, the ammonium diuranate cake is calcined to drive off ammonia and give a product assaying 99 pct U_3O_8. The ammonium nitrate solution from the precipitation step is recycled for wetting the acid-cured material.

Advantages of the process are that little water is needed, a minimum number of steps are necessary to obtain a high grade precipitate, and reagent requirements are low. There are two disadvantages: 1) the acid-cure procedure is not particularly effective on ores requiring an oxidant for good uranium solubilization and 2) recovering entrained TBP and kerosene from the percolation leach tails makes the process more costly than conventional processes.

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The opinions expressed herein are those of the authors and do not necessarily represent those of the U. S. Bureau of Mines or the Atomic Energy Commission.

THE SEARCH FOR LOWER COSTS
— PROBING THE PROCESSES

Atmospheric vs Pressure Leaching of Uranium Ores

Pilot plant studies reveal that high temperature, high pressure leaching of uranium ores in alkaline solutions cuts leach time 90 to 95 pct. Leach times may be cut in half by using existing Pachuca tank equipment at moderate temperatures and pressures.

By R. G. Beverly
A. W. Griffith
W. A, Millsap

THE Grand Junction Pilot Plant, operated by National Lead Co. Inc., for the U. S. Atomic Energy Commission, is engaged in the amenability testing of orebodies to establish design and cost data for commercial mills and to test new processes for recovery of uranium from ores. Test work was performed to study the effects of several variables on leaching of uranium ores in carbonate solutions. Many of these variables had been investigated in the laboratory, but pilot plant tests were desirable to evaluate their importance in semi-works equipment and to predict optimum operating conditions for future commercial mills. The results of these tests should serve as a guide in selecting the most efficient and economical method of leaching uranium ores amenable to a carbonate process.

This article is concerned with a process in which uranium is extracted from the ore by a hot Na_2CO_3-$NaHCO_3$ solution; the uranium-bearing solution is separated from the solid residue by filtration, and uranium is then precipitated by chemical means.

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Fig. 1—Grand Junction pilot plant

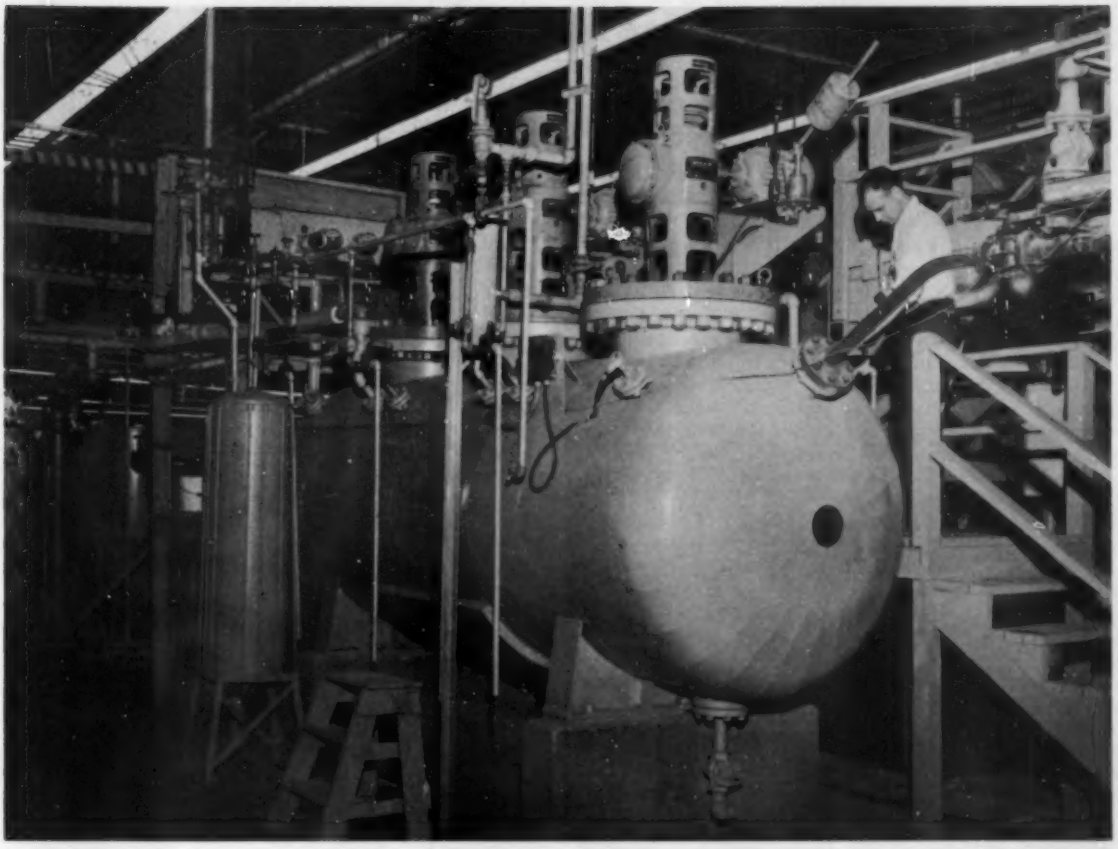


Fig. 2—Pilot plant 1200-gal autoclave. Measuring more than 12 ft long, the unit is provided with three 5-hp 230-rpm mechanical agitators. Inside diameter is 4½ and it is filled to a level of 3½ ft.

Chemistry of Alkaline Leaching

The important reactions involved are shown below. The literature contains a number of detailed reports on the chemistry of alkaline leaching. [8, 9, 10]

$$2UO_2 + O_2 \rightarrow 2\,UO_3 \qquad [1]$$

$$UO_3 + H_2O + 3\,Na_2CO_3 \rightarrow Na_4UO_2(CO_3)_3 + 2\,NaOH \qquad [2]$$

$$Na_4UO_2(CO_3)_3 + 4\,NaOH \rightarrow Na_2UO_4 + 3\,Na_2CO_3 + 2\,H_2O \qquad [3]$$

$$NaOH + NaHCO_3 \rightarrow Na_2CO_3 + H_2O \qquad [4]$$

$$UO_3 + Na_2CO_3 + 2\,NaHCO_3 \rightarrow Na_4UO_2(CO_3)_3 + H_2O \qquad [4a]$$

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4 \qquad [5]$$

$$4\,FeS_2 + 15\,O_2 + 16\,Na_2CO_3 + 14\,H_2O \rightarrow 4\,Fe(OH)_3 + 8\,Na_2SO_4 + 16\,NaHCO_3 \qquad [6]$$

$$SiO_2 + 2\,Na_2CO_3 + H_2O \rightarrow Na_2SiO_3 + 2\,NaHCO_3 \qquad [7]$$

The first reaction shows the oxidation of uranium from quadrivalent to hexavalent. Reaction 2 represents the dissolution of uranium by the carbonate. In the absence of bicarbonate, uranium will precipitate as a sodium uranate, reaction 3, as the hydroxide increases. Therefore, sodium bicarbonate is added, reaction 4, and the dissolution of uranium in the carbonate and bicarbonate solutions can be represented by 4a, the summation of equations 2 and 4. Reaction 5 is a carbonate consumer which usually eliminates the advantages of using alkaline leaching for ores containing appreciable amounts of gypsum. Although reactions 6 and 7 also consume Na_2CO_3, part of the sodium ion results in $NaHCO_3$, which is useful to the process. The sodium sulfate is of no use and, as far as is known, has no effect on leaching. Sulfate concentrations up to 50 g per liter have been experienced in the pilot plant with no detrimental effect and laboratory leach tests made with sulfate concentrations as high as 100 g per liter showed no decrease in uranium extraction.

The silica reaction (Eq. 7), which is favored by temperatures above 250°F, may decrease filtration rates, and the silicate upon cooling may precipitate and occlude some uranium. However, in pilot plant autoclave leaching operations, this has not happened, even at temperatures of 275°F. Filtration rates on residues from high temperature leaching have been somewhat lower than those from leach tests at 180°F. Although the exact reason for the lower filterability has not been established, the formation of silicates probably is contributory.

Alkaline Leach—Filtration Pilot Plant

The flowsheet of the Alkaline Leach—Filtration Pilot Plant is shown in Fig. 10 and has been described in detail in other reports. [1, 8]

The ore, after being crushed to −3/16-in., is fed to a 3 x 5-ft ball mill operating in closed circuit with an 18-in. rake classifier. Recycled mill solution is used for grinding solution. The classifier overflow

is pumped to a 12 x 8-ft thickener to thicken the pulp and to maintain a constant pulp density to the leach circuit.

Pachuca Tanks: The leach circuit consists of either four 4 x 47-ft Pachuca tanks in series or a 4.5 x 12-ft autoclave. The four Pachucas provide a leach contact time of 96 hr with a 50 pct solids slurry at a feed rate of 12 tons of ore per day. Each Pachuca has a 3-in. internal air lift for pulp circulation, two ¼-in. pipes in the cone for adding aeration air, and four 1-in. steam pipes to maintain desired pulp temperatures. The vessels are insulated with 1-in. Fiberglas and a corrugated aluminum covering. The 45-ft elevation to the discharge level provides a pressure of approximately 30 psig in the bottom of the tank when filled with a 50 pct solids pulp. Although the Pachucas are usually operated at atmospheric pressure on top, the installation of a pressure regulating valve on the top of each tank has permitted operating under pressure up to 20 psig on top, which results in a pressure of 50 psig at the bottom. The Pachucas are shown in Fig. 4.

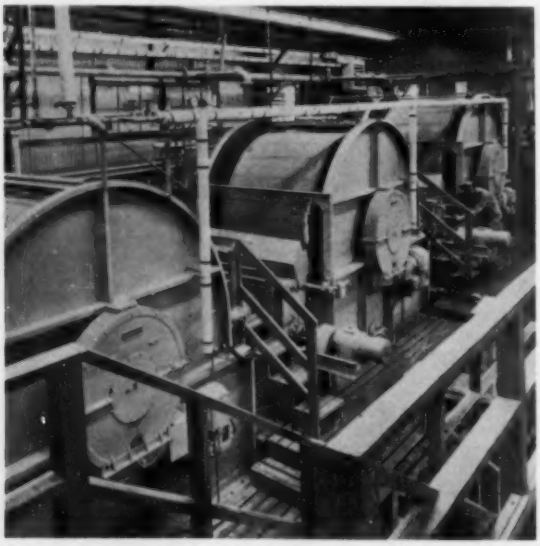
Autoclave: When the autoclave is in operation, it replaces the Pachucas in the circuit. Pulp is heated by steam in a double pipe heat exchanger. Retention time in the autoclave is approximately 6.5 hr at 50 pct solids. The pulp is maintained at the desired leaching temperature by automatically controlled electrical strip heaters fastened to the bottom of the autoclave between the shell and the insulation. However, only a small amount of heat is required for this purpose. The autoclave is shown in Fig. 2.

The horizontal autoclave is 4½ ft in diameter, 12 ft long, with 1½-ft dished heads, and is divided into three sections by double baffle plates. Each section is agitated with a 5-hp turbine-type agitator equipped with a 5-blade 16-in. turbine. Capacity of the vessel is approximately 1200 gallons. Air is added through a ½-in. line discharging beneath each agitator. The quantity of air input is regulated by an automatic control valve. A spring-loaded reducing valve controls the pressure in the autoclave. Pulp is discharged by the internal pressure through an intermittently operated plug valve. The discharge valve is operated automatically by a pulp level control and is open approximately 1 min at 20-min intervals. Temperature and pressure losses in the discharge line between the autoclave and the top of a Pachuca which is used as a surge vessel dissipate enough heat and pressure so that very little flashing of steam takes place at the discharge. As yet, no attempt has been made to utilize the heat in the discharging pulp for preheating the incoming pulp. It is interesting to note that the Canadians at the Beaverlodge mill estimate a savings in heating costs of $0.20 per ton by this method of heat recovery from autoclave leach pulp.[7]

The leached pulp is discharged from the Pachucas or autoclave to the first of three 4 x 8-ft cloth-covered vacuum drum filters operating in series. Provisions are made to add filtering aids to the pulp feed for each filter. The filtrate from the first filter is pregnant liquor containing the solubilized uranium. This liquor is pumped through a plate and frame clarification press and then to the precipitation tank. The solids residue is washed on the second and third filters and is pumped to tailings. The repulp solution and wash to the second filter is barren filtrate from the regeneration tank. The solids fed to the third filter are repulped and washed with water. Filtrate from the second filter is returned to the grinding circuit, and filtrate from the third filter is used as wash on the first filter.

Factors Affecting Leach

At atmospheric pressure, relatively long contact times are required for alkaline leaching—50 to 100 hr. For good uranium extraction, a hot leach is required, and temperatures above 180°F, up to 250° or 275°F, decrease the contact time required to 6 or 10 hr. Oxidation of the reduced uranium in the ore can be accomplished chemically, usually by $KMnO_4$, or by air. Higher pressures increase the solubility of oxygen in the leaching solution through



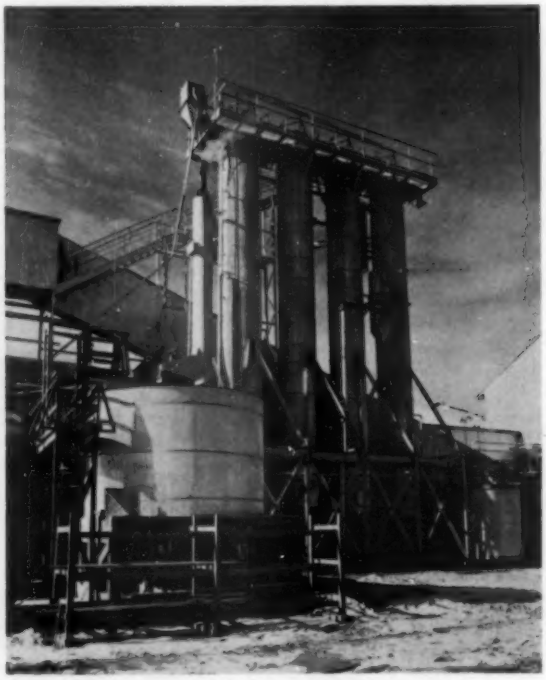


Fig. 3—ABOVE: Rotary drum filters for filtering leach pulp and washing residue. Fig. 4—RIGHT: Pachuca leach tanks used in pilot plant. It is 45 ft from the bottom of the tank to pulp overflow line, and a ½-in. line provides air for the 3-in. air lift. Inside diameter is 4 ft.

When the pressure was raised to 50 psig and the

the Pachuca tanks. This difference is presently un-

Table I. Autoclave Leach Studies on La Sal Ore*

Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ore head assay, pct U_3O_8	0.350	0.307	0.294	0.354	0.328	0.323	0.332	0.309	0.346	0.358	0.349	0.352	0.402	0.437	0.376
Leach Conditions†															
Pressure, psig	30	33	30	50	53	54	51	55	53	53	70	70	70	70	70
Temperature, °F	225	250	250	225	251	250	250	274	271	273	235	250	250	250	267
Air, std cu ft per ton ore	952	665	1060	990	738	1110	1475	738	1110	1475	990	183	1100	2080	990
Extraction															
Final residue, pct U_3O_8	0.025	0.023	0.021	0.018	0.012	0.011	0.013	0.022	0.017	0.018	0.016	0.014	0.014	0.014	0.014
U_3O_8 extraction, pct															
after 2.4 hr	86.3	88.9	89.5	88.7	93.8	94.1	93.4	89.6	92.2	92.7	90.8	93.5	94.8	94.7	94.1
after 4.8 hr	91.1	91.2	91.8	92.9	95.3	96.0	95.5	91.6	94.2	94.4	94.6	95.2	96.0	96.1	95.7
after 7.2 hr	92.9	92.5	92.9	94.9	96.3	96.6	96.1	92.9	94.5	95.0	95.4	96.0	96.5	96.8	96.3
Terminal Reagent Concentration															
g Na_2CO_3 per liter	39.1	40.3	39.0	35.0	39.7	38.3	41.1	38.1	39.7	41.9	37.5	40.1	40.5	37.6	35.0
g $NaHCO_3$ per liter	10.5	12.6	12.0	13.5	13.2	13.3	13.1	16.7	15.2	13.8	14.0	20.8	19.3	17.9	16.3

* Pulp specifications:
Pulp Density: 50 pct solids
Average Grind: 1.1 pct +65 mesh, 71.5 pct −200 mesh
Reagent Concentration (Grinding Solution): 49 g Na_2CO_3 per liter, 8 g $NaHCO_3$ per liter
Ore Feed Rate: 11.8 tons per day
† Underline indicates major variable changed from previous test.

increased partial pressure and permit the use of less total air addition. Reagent concentrations are usually maintained in the range of 40 to 60 g Na_2CO_3 and 10 to 20 g $NaHCO_3$ per liter. Agitation should be adequate to keep the pulp in a constant and thoroughly fluid regime. The dispersion of air throughout the pulp is also dependent on the mixing device. Most ores require grinding to grain size in order to permit contact of the uranium particles with the leach solution. Grinds usually average 1 to 5 pct +65 mesh and 50 to 75 pct −200 mesh. Pulp densities are usually controlled between 40 and 55 pct solids, a range which permits adequate mixing and prevents rapid settling of the coarser sands.

The following factors are of importance in alkaline leaching.[2,6,10]

Leach Contact Time: The required contact or retention time of the ore in the leach solution is dependent upon temperature, efficiency of oxidation and agitation, and to an extent on the other variables. Fig. 9 shows the results of alkaline leach studies conducted on La Sal ore, from the Big Indian Wash area of Utah.[4] Of the total leach extraction, a large part takes place in the first few hours, providing sufficient oxidation and agitation are present, but a much longer time is required to raise the extraction to a leveling-off point. Pilot plant results at higher pressures have shown even a more pronounced effect with 95 pct of the total leaching taking place within the first 1 hr, at most, 2 hr.

Table II. Pachuca Leach Studies on La Sal Ore*

Test No.	1	2	3	4	5
Ore head assay, pct U_3O_8	0.429	0.434	0.379	0.350	0.394
Leach Conditions†					
Top pressure, psig	0	0	20	20	20
Temperature, °F	183	182	217	222	222
Air,‡ std cu ft per ton ore	2500	5000	830	1660	3320
Number of Pachucas	3	3	2	2	2
Extraction					
Final residue, pct U_3O_8	0.018	0.009	0.023	0.011	0.009
U_3O_8 extraction, pct					
after 16 hr	77.9	88.7	82.3	87.4	92.9
after 32 hr	91.6	95.9	93.9	96.9	97.7
after 48 hr	95.8	97.9	—	—	—
Terminal Reagent Concentration					
g Na_2CO_3 per liter	48.6	49.9	48.7	45.0	44.6
g $NaHCO_3$ per liter	13.9	12.6	11.4	12.0	14.6

* Pulp specifications:
Pulp Density: 50 pct solids
Average Grind: 2.3 pct +65 mesh, 68.1 pct −200 mesh
Reagent Concentration (Grinding Solution): 52 g Na_2CO_3 per liter, 9 g $NaHCO_3$
Ore Feed Rate: 17.4 tons per day
† Underline indicates major variable changed from previous test.
‡ In addition to air lift air which amounted to 4 std cfm per Pachuca.

Leach Temperature: Fig. 5 shows the comparison of autoclave and Pachuca leaching and the relationship between increased temperatures and pressures on extraction and contact time. These studies were made while processing Todilto Black Limestone from Grants, New Mexico,[6] and Rio de Oro ore from Ambrosia Lake, New Mexico.[5] Todilto Limestone contains approximately 81 pct $CaCO_3$ and Rio de Oro ore treated in the pilot plant assayed 7.5 pct $CaCO_3$. Leaching at atmospheric pressure and 180°F required 10 to 20 times the contact time necessary at elevated pressures and at temperatures in the range of 255° to 265°F.

Partial Pressure of Oxygen: Pertinent data from a series of autoclave tests are shown in Table I, and the more important results are shown graphically in Figs. 6 and 7. Effectively no uranium in the reduced state will be extracted from the ore without oxidation. Oxidation can be accomplished by chemical means, usually $KMnO_4$ in alkaline solutions, or by air, as was done in all tests in the pilot plant. The solubility of oxygen increases approximately directly proportional to its partial pressure, i.e.

$$X_{O_2} = \frac{P_{O_2}}{H} \text{ where } \begin{matrix} X = \text{solubility} \\ P_{O_2} = \text{partial pressure of oxygen} \\ H = \text{proportionality constant} \end{matrix}$$

As temperature increases, the vapor pressure of water increases, which effectively reduces the oxygen partial pressure for any given total pressure on the system.

If air were not added continuously, the partial pressure of oxygen would not remain constant throughout the leach because a significant quantity of oxygen is consumed. Consequently, air is flowed through the system to replenish this oxygen. The most suitable flow would depend only on the rate at which oxygen reacts if pure oxygen gas were being supplied, but since air is used, the whole gaseous phase must be replaced frequently in order to keep the partial pressure of oxygen at its maximum for the given conditions of temperature and total pressure.

During the autoclave studies the lowest extractions (92 to 93 pct) were obtained at a pressure of 30 psig even though the temperature was increased from 225° to 250°F and the air was also increased.

An agitator which efficiently mixes the pulp will tend to break the air bubbles, thus increasing the

When the pressure was raised to 50 psig and the temperature to 250°F, extraction increased to over 96 pct. Higher air rates at these conditions gave no appreciable improvement. Increasing the temperature to 270° to 275°F dropped extraction to 93 pct but higher air rates at these temperatures showed a significant improvement.

Comparing Tests 5 to 7 with 8 to 10 in Table I clearly shows the effect from increasing temperatures without a corresponding increase in pressure; extraction at a pressure of 70 psig and a temperature of 250° to 270°F was no better than at 50 psig and 250°F. In the autoclave, a temperature of 250°F, a pressure of 50 psig, and air addition between 800 and 1000 std cfm per ton of ore results in highest extractions.

The Pachuca studies, shown in Table II and Fig. 8, were made primarily to determine the effect of varying quantities of aeration air at temperature levels of 180° and 220°F. Aeration air is usually held in the range of 20 std cfm per Pachuca (1.6 std cfm per sq ft cross sectional area). Between 3.0 and 5.0 std cfm is used in each Pachuca air lift. As can be noted in Table II and Fig. 8, reducing the air below 20 std cfm per Pachuca lowered extraction. However, 3320 std cfm of air per ton with a 32-hr leach at 20 psig and 220°F was as effective as 5000 std cfm per ton with a 48-hr leach at atmospheric pressure and 180°F.

In general, uranium recovery decreased as the aeration air rate was decreased. It is evident from these data that extraction rates increased with higher temperature and pressure. As in the autoclave, the dissolution rate increases with temperature and oxygen partial pressure. However, temperature changes were not high enough to affect significantly the oxygen solubility.

Sodium Carbonate and Bicarbonate Concentration: Reagent concentrations in alkaline leach solutions are usually controlled in the range of 40 to 60 g Na_2CO_3 and 10 to 20 g $NaHCO_3$ per liter. They may be varied over a wider range, particularly much higher in carbonate strength, but pilot plant studies have shown no major effect on extraction between 25 and 60 g Na_2CO_3 per liter and 5 to 25 g $NaHCO_3$. At low concentrations filtration rates were appreciably reduced. The optimum amount of $NaHCO_3$ should be determined and the concentration held at that level because the higher the $NaHCO_3$ concentration in the pregnant liquor, the more caustic soda will be required for precipitation.

It has been noted that with carbonate consuming ores, more carbonate is consumed in pressure leaching than at atmospheric pressure. On some ores the bicarbonate strength in the grinding solution has been as low as 5 g per liter, yet the solution will leave the leaching step at 15 g per liter or higher. Other ores will result in a complete reversal of this chemistry and produce some carbonate at the expense of the bicarbonate. The amount of uranium in the leaching solution did not have an effect on extraction in the pilot plant.

Reagent consumption can be broken down as an average of 16 lb Na_2CO_3 and 18 lb NaOH per ton of ore. Fuel oil consumption for regeneration will vary between 0.4 and 0.6 gal No. 2 fuel oil per ton. Reagent consumption data from one amenability test in which the ore was treated in the autoclave and the Pachucas indicate from 5 to 8 lb more NaOH per ton of ore are needed in the autoclave than in the Pachuca tanks. This difference is presently under further investigation.

Agitation of Pulp: Pachuca leaching utilizes internal air lifts for agitation of the pulp. Air lifts are advantageous in that no moving parts are involved, but properly designed mechanical agitators assure far more complete mixing. Where mechanical agitators will tend to break down particle size somewhat, air lifts have little tendency to do so.

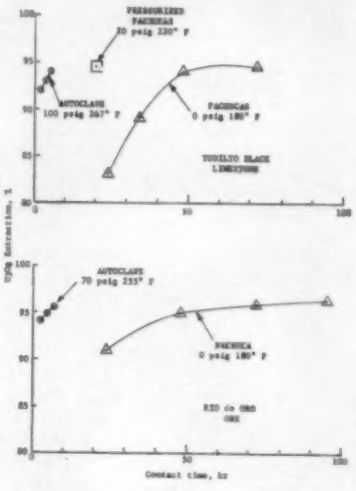


Fig. 5—Contact time vs. temperature and pressure for two ores.

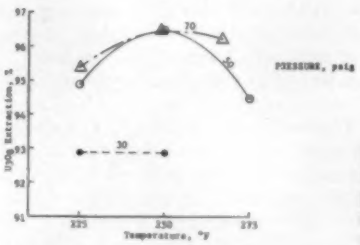


Fig. 6—Effect of temperature and pressure, autoclave studies on La Sal ore.

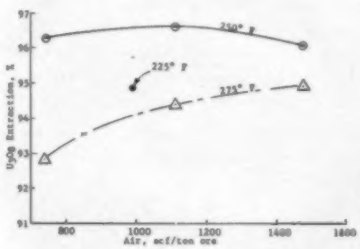


Fig. 7—Effect of air addition at 50 psig, autoclave studies on La Sal ore.

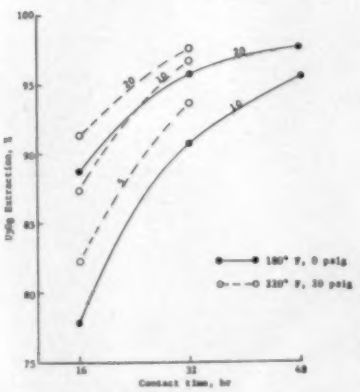


Fig. 8—Pachuca leach studies on La Sal ore. Numbers on plots refer to air addition, in std cu ft per min per Pachuca.

An agitator which efficiently mixes the pulp will tend to break the air bubbles, thus increasing the air to pulp surface contact area. The liquid film surrounding the air bubbles is reduced in thickness by thorough agitation which increases the mass transfer coefficient of oxygen through the film and into solution. Greater oxidation effect of the air is also accomplished if, through complete mixing, the air is retained in the pulp a longer time and bubbles of air do not rise immediately to the surface from their point of discharge into the pulp.

Some comparisons of leaching in Pachucas and in conventional mechanically agitated leach tanks indicate contact time is reduced appreciably by more thorough agitation, but more investigative work needs to be done.

Fineness of Grind: Carbonate liquors do not tend to dissolve interstitial material and it is necessary to grind to the grain size of the ore to permit contact of the uranium particles with carbonate solution. Pilot plant grinding, which reduces the ore to 2 pct +65-mesh and 70 pct −200-mesh material, has been adequate for high uranium extraction.

Pulp Density: Degree of agitation is related to pulp density. If pulp densities are too high to permit adequate mixing, extraction will suffer. When using air agitation, such as air lifts in the Pachucas, pulp densities greater than 50 pct solids can reduce extractions, other factors such as temperature and contact time being equal. An example of this is one test made in the Pachuca tanks on Rio de Oro ore. At 51 pct solids, extraction was 95.4 pct in 60 hr time and 96.5 in 100 hr. When leaching at 59 pct solids, extractions were 94.7 pct in 60 hr and 95.4 pct in 100 hr, showing approximately a 1 pct lower recovery or 0.05 lb U_3O_8 per ton.

Autoclave Corrosion

The Canadians at the Beaverlodge mill have experienced a pitting type of corrosion at the froth or splash line in the autoclave, and little or no corrosion has been observed elsewhere. The attack is attributed to the high sulfide content of the ore and takes place in the autoclaves near the head of the leach circuit. The reaction is thought to be from sulfurous or sulfuric acid which is formed from the

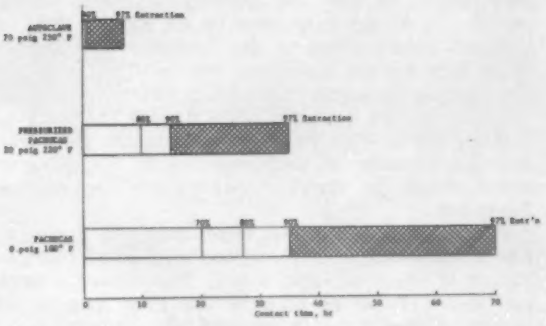


Fig. 9—Effect of temperature and pressure on contact time using La Sal ore.

sulfide as the pulp, which splashes on the walls, is diluted by condensed water vapor. The solution near this froth area is changed from alkaline to acidic.

A clad belt of low carbon, type 316, stainless steel in the area of the pulp level could minimize this corrosion problem. Possibilities of electrolytic corrosion are also being investigated in Canada.

National Lead Co.'s autoclave has been in operating service 4 months during which 1400 tons of ore have been leached. A recent inspection showed no signs of corrosion at or below the pulp level. Above the pulp level there were several deposits of hard mud-like material. When these deposits were scraped off, there were indications of pitting corrosion beneath some but not all of the deposits. The majority of the pits were so small or shallow that they were not measured. It was noted during the inspection that the deposits were acidic, testing in the range of pH 5 to 6 with litmus paper. Sulfide content of the ores treated in the pilot plant has been considerably less than those treated in autoclaves at Beaverlodge.

A summary of average utility consumption figures is shown in Table III along with a rough estimate of the cost of steam and power for the autoclave and for Pachuca tanks operated with and without pres-

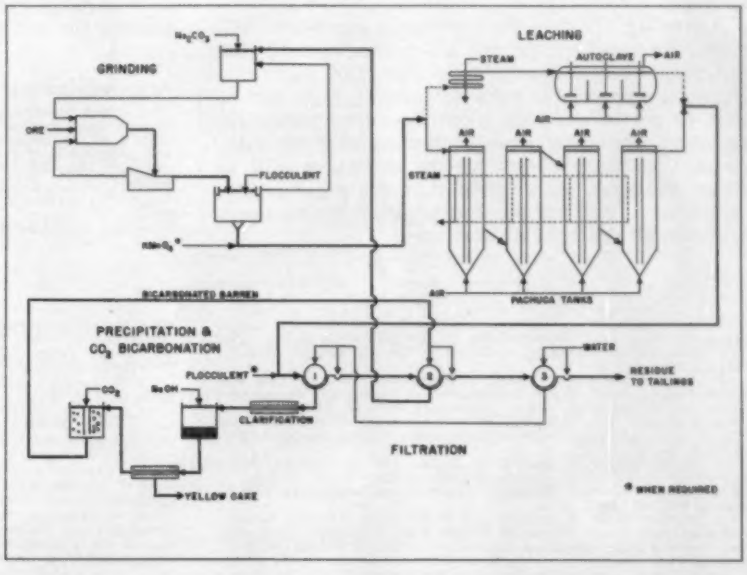


Fig. 10—Flow sheet of the alkaline leach filtration process used at the Grand Junction pilot plant. Either Pachuca tanks or the autoclave may be used, all other factors remaining constant.

sure applied on top. The leaching conditions shown resulted in 97 pct extraction on La Sal ore.

Steam consumption in the Pachucas was almost twice that for the autoclave, 800 to 820 lb per ton compared with 430 lb. Theoretical heat balances did not corroborate the pilot plant figures for the Pachucas, due to high heat losses from the Pachucas and the quantity of heat expelled in the form of water vapor in the air leaving the top of the Pachucas.

It is estimated that heat losses from the Pachucas due to radiation and convection may be as high as 35 pct of the total heat input. The radiation area per unit volume of pulp in the pilot vessels, of course, is very large (approximately 5 times) compared to commercial size tanks. In commercial mills, a large amount of the heat in the pulp leaving the leach circuit operated at elevated temperatures would be recovered both for reasons of heat economy and to prevent excessive flashing of steam. The steam consumptions at the bottom of Table III are calculated on the basis of recovery of heat from the exit pulp, 250° in the autoclave and 220° in the pressurized Pachucas, down to a temperature of 150°F. Further cooling is not desirable as it would be detrimental to filtration. Were the heat recovery equipment in use in the pilot plant, steam consumption by calculations would be 800 lb per ton for the Pachucas, 660 lb per ton for pressurized Pachucas, and 217 lb per ton for the autoclave. At a steam cost of $0.80 per 1000 lb, a savings in pilot plant steam costs of approximately $0.47 per ton of ore could thus be realized by operation of the autoclave and $0.11 by the pressurized Pachucas. Theoretical figures for a commercial mill indicate steam use for leaching may be about 500 lb per ton for Pachucas, 350 lb per ton for pressurized Pachucas, and 200 to 250 lb per ton for autoclaves.

Power requirements in the autoclave for air compression and agitation are higher than for the Pachucas. Mixing in the autoclave is, of course, very thorough compared to the Pachucas. Although no attempt has been made to determine if the agitation in the autoclave is in great excess, it is felt the agitators, with a total of 15 connected horsepower, would be adequate for a vessel of two or three times the size of the existing one, which has a capacity of 1200 gal.

Assuming: 1) that the previously mentioned mill steam consumption figures are reasonable; 2) that the power requirements from the pilot plant Pachucas are applicable for a commercial mill; and 3) that 40 pct of the pilot plant autoclave power for agitation would be required in a commercial autoclave, then utility costs for the autoclave will be about $0.10 per ton cheaper than for pressure Pachucas and $0.25 per ton cheaper than for Pachucas operated at atmospheric pressure.

Table III. Pilot Plant Steam and Power Costs

Pilot Plant	Pachucas	Pressurized Pachucas	Autoclave
Conditions			
Ore, tons per day	17.4	17.4	11.8
Leach time, hr	48	32	7
Pressure, psig	0	20	50
Temperature, °F	180	220	250
Air, std cu ft per ton ore	6000	3960	1110
Steam, lb (100 psig) per ton	800	820	430
Power for agitation, Kw-hr per ton	—	—	12.9
Power for air, Kw-hr per ton	8.7	5.7	1.62
Total power, Kw-hr per ton	8.7	5.7	14.5
Estimated Operations Costs Per Ton			
Cost of steam at $0.80 per 1000 lb, $	0.64	0.66	0.35
Cost of power at $0.012 per Kw-hr, $	0.10	0.07	0.17
Cost of steam and power, $	0.74	0.73	0.52
With Pulp Heat Recovery System, Calculated Figures			
Steam, lb (100 psig) per ton	800	660	217
Cost of steam at $0.80 per 1000 lb, $	0.64	0.53	0.17
Cost of steam and power, $	0.74	0.60	0.34

To select the best leach vessel for the job, costs of operation must be balanced against other factors such as type of ore to be treated, capital cost, maintenance, space requirements, reagent consumption, filterability of leached pulp, and the variety of ores to be treated.

Pilot plant amenability tests have shown the autoclave to be more versatile than the Pachucas in handling different ores. Where the leach time for best extraction in the Pachucas has varied from 48 to 120 hr, 6 to 7 hr retention time in the autoclave has been adequate for all ores treated. A Pachuca not under pressure has a limited maximum operating temperature. An autoclave permits a fairly wide range of operating temperatures and pressures and leaching conditions can be varied to suit the ore.

Pilot plant tests using the Pachucas under pressure have not been extensive. However, available results indicating the advantages of operating at a small pressure on top justify any additional initial investment over Pachucas designed to operate at atmospheric pressure. Actually, pressurized Pachucas will probably be cheaper to build, for although somewhat heavier plates will be required for construction, fewer Pachucas will be required.

As a result of the recent interest in alkaline leaching of ores from the Ambrosia Lake area of New Mexico and the applicability of the process to high lime ores, priority is being given this pilot plant toward further investigation of the variables discussed.

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Neither the Government nor the AEC makes any warranty or assumes liability for any information disclosed in this report.

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THE SEARCH FOR LOWER COSTS
—— PROBING THE PROCESSES

Ammonium Carbonate Pressure Leaching of Uranium Ores

By B. G, Langston
R. D. Macdonald
F. M. Stephens, Jr.

WITH the development of uranium ores that contain substantial amounts of acid-consuming compounds, the alkaline leach has become an attractive method for extraction. Considerable work has been done on both atmospheric and pressure-leaching with aqueous solutions of sodium carbonate and sodium bicarbonate as the lixiviants.[1,2,3] For the treatment of uranium-bearing limestones and other high-lime (CaO) ores, the sodium carbonate leach has proven attractive because it avoids the high reagent consumption incurred by the reaction of sulfuric acid with lime.

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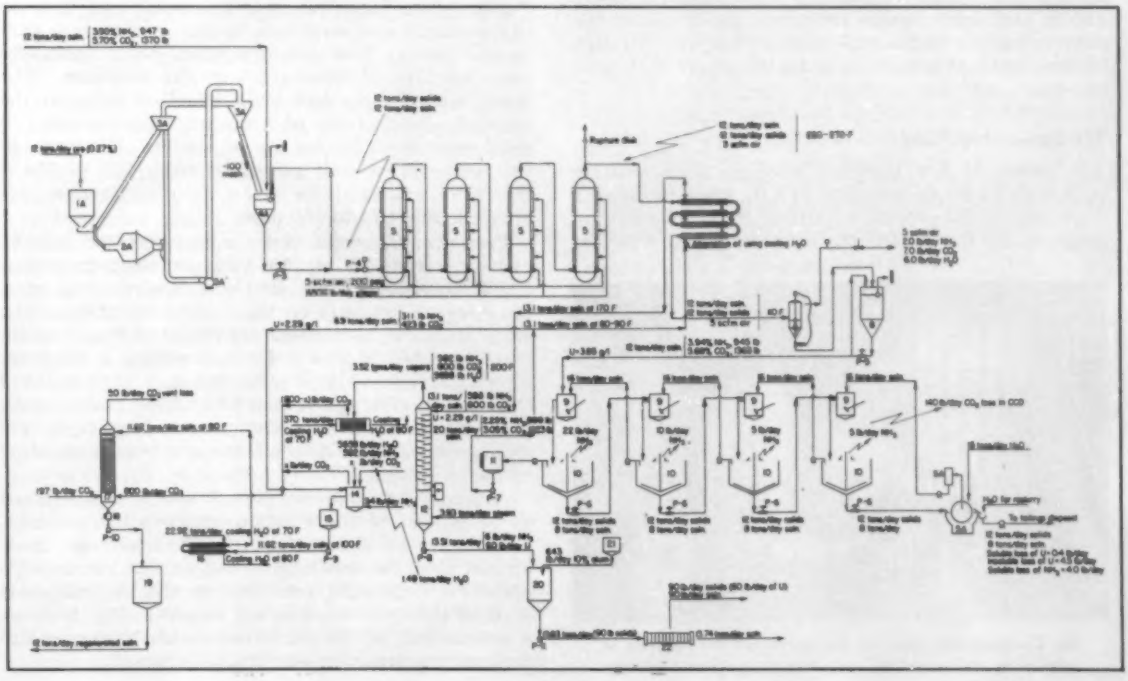
In addition, the corrosion problems with sodium carbonate are negligible as compared with those encountered in the acid-leach system. The sodium carbonate leach, however, does not yield as high an extraction of the uranium as the acid leach and is not attractive for economic reasons when treating ores that are high in sulfates or sulfides.

Although in the sodium carbonate leach process the bulk of the sodium carbonate can be reclaimed and returned to the system, some reagent is consumed by contact with gypsum, pyrite, and silica. Ammonium carbonate would have no advantage over sodium carbonate with respect to the consumption resulting from the presence of gypsum or pyrite in the ores, but consumption resulting from the reaction of sodium carbonate with silica would be

Fig. 1—Process flowsheet for ammonium carbonate leach pilot plant.



eliminated. It was believed that steam stripping of the ammonium carbonate leach solutions to precipitate the uranium and recover the ammonia would give the process an advantage over the sodium carbonate leach, where sodium hydroxide must be supplied to precipitate the uranium.

Chemistry of the Process

If it is assumed that dissolution of uranium in the ore by an ammonium carbonate solution forms ammonium uranyl carbonate, the following equations express the chemistry of the process:

$$9(NH_4)_2CO_3 + U_3O_8 + 1/2O_2 + 9H_2O \rightarrow 3[(NH_4)_4 \cdot UO_2(CO_3)_3 \cdot 2H_2O] + 6NH_4(OH) \quad [1]$$

$$NH_4(OH) + NH_4HCO_3 \rightarrow (NH_4)_2CO_3 + H_2O \quad [2]$$

$$(NH_4)_4UO_2(CO_3)_3 + \text{heat} \rightarrow 4NH_3(\text{gas}) + 3CO_2(\text{gas}) + UO_3 \cdot 2H_2O(\text{ppt}) \quad [3]$$

Because, at atmospheric pressure, ammonium uranyl carbonate decomposes at 212°F, pressure is utilized in the leaching step to minimize the loss of ammonia and carbon dioxide. In addition, to obtain maximum extraction of the uranium from many of the ores, which contain both quadrivalent and hexavalent uranium, pressure facilitates oxidation to the readily soluble hexavalent state in the presence of free oxygen. Although potassium permanganate is an effective oxidizing agent in the ammonium carbonate pressure leach, air is equally effective and much less expensive.

Equation 2 is of interest because ammonium bicarbonate is not required in an ammonium carbonate leach, as is sodium bicarbonate in a sodium carbonate leach. The formation of free ammonium hydroxide within the concentrations obtained in this study had no adverse effect on the dissolution of uranium.

The precipitation of the uranium from the pregnant solution, Equation 3, involves passing steam through the solution, heating it to approximately 212°F, and using it as a sweeping gas to aid in the removal of ammonia and carbon dioxide. Air can be employed as a substitute for steam as a sweeping gas.

The Integrated Plant

A series of five pressure-leaching towers 10 ft high with an inside diameter of 4 in. were fabricated for study of the process variables. Fig. 2 is a photograph of the towers and the countercurrent washing and precipitation tower that was added later to give an integrated plant for evaluation of the unit processes required for both the extraction and recovery of uranium.

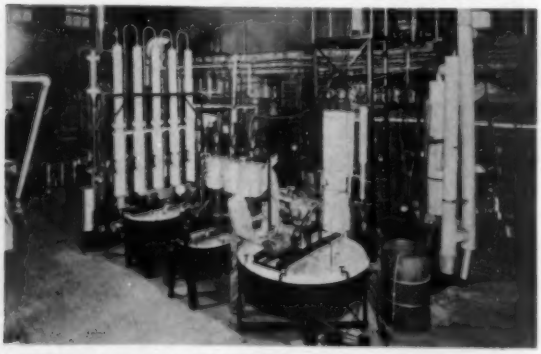


Fig. 2—Integrated plant for the extraction and recovery of uranium by the ammonium carbonate pressure-leach process.

Fig. 1 is a flowsheet of the process as visualized for a pilot-plant operating at a feed rate of 12 tons per hour. Although other modifications of the flowsheet might be employed, for the purpose of demonstrating an integrated system one utilizing a dry grind is shown.

Development of the Leaching Conditions

To determine the amenability of high-lime ores to an ammonium carbonate pressure leach for the extraction of uranium, temperature, pressure, strength of solution, and the amount of oxidation required to convert the quadrivalent uranium to the hexavalent state were considered.

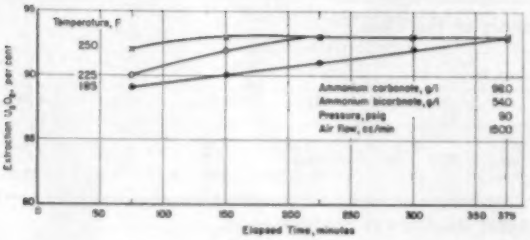
Nine different ores were studied either by small-scale testing or by operation of the pressure leaching towers, but the major emphasis was placed on three of the ores that contained varying amounts of lime (CaO). Table I gives the chemical analysis of these three ores.

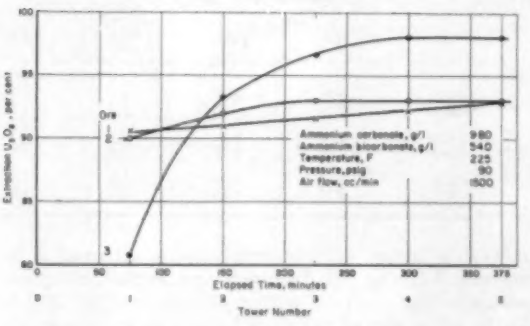
Because over 85 pct of the uranium was present in the −200-mesh fractions when the ore was ground to pass a 100-mesh screen, it was believed that grinding to a finer particle size would not materially affect the leaching characteristics of the ore. For most ores a slurry with a 50 pct pulp density was sufficient to prevent classification in the towers.

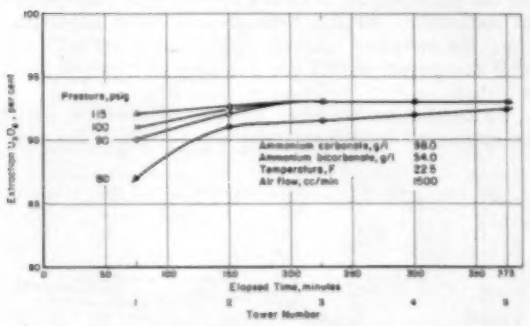
Temperature: A series of tests was run in the towers at temperatures of 185, 225, and 250°F. A pressure of 90 psig and a solution containing 98 g $(NH_4)_2CO_3$ and 54 g NH_4HCO_3 per liter were chosen arbitrarily, based on preliminary test runs in a batch autoclave. In addition, to provide for oxidation of any quadrivalent uranium in the ore, 1500 cu cm of air per min were passed through the towers. This was the smallest flow rate that could be maintained without plugging the air line with slurry. Fig. 3 shows the effect of temperature and time on the extraction of uranium by the ammonium carbonate leach. The primary effect of temperature was the rate of dissolution of the uranium. The leach temperature had little effect, if any, on the maximum extraction of uranium from the ore; in each case about 93 pct was extracted. However, as the temperature was increased from 185 to 250°F the time required for maximum extraction decreased from 375 to 150 min.

Pressure: A series of tests was run varying the pressure from 80 to 115 psig. A temperature of 225°F was chosen to obtain comparative data as to the effect of pressure on the dissolution of uranium, since at 250°F, approximately 92 pct of the uranium was extracted in Tower 1, representing a retention time of 75 min. Fig. 4 gives the data obtained and shows that, although pressure had little effect on the extraction, when extended retention periods are employed, pressure does affect the rate of dissolution of the uranium.

Although the data in Figs. 3 and 4 are believed to be typical of the relation between temperature, pressure, and the extraction of uranium, it is known that the position of the curves varies with each ore, depending probably on the mineralogical state of the uranium-bearing mineral. Fig. 5 shows a comparison of the performance of three ores run through the pressure leaching towers.







TOP: Fig. 3—Effect of temperature and time on the extraction of uranium. CENTER: Fig. 4—Effect of pressure and time on the extraction of uranium. BOTTOM: Fig. 5—Comparison of the performance of three ores tested in the ammonium carbonate pressure leaching towers.

Oxidation with Air and Oxygen-Enriched Air: Tests were run to determine the amount of air required to convert uranium to the hexavalent form. A temperature of 225°F, a pressure of 90 psig, and a solution containing 98 g $(NH_4)_2CO_3$ and 54 g NH_4HCO_3 per liter were employed and the air flow varied from 1500 to 6000 cu cm per min. Within this range, the amount of air passed through the towers had no effect either on the rate of dissolution of the uranium or the final extraction.

An analysis of the exhaust gases from the towers showed that they contained 17 pct O_2 even at the lowest flow rate studied. Thus, it was concluded that a flow rate of 1500 cu cm per min was sufficient for oxidation of any quadrivalent uranium in the ore. However, because the partial pressure of oxygen in the system might affect the rate of oxidation, a test was run with oxygen-enriched air. Oxygen content of the air was enriched to 30 pct, but addition of this amount of oxygen did not improve either the rate or final extraction of uranium. Although pressures greater than 90 psig or a gas with greater than 30 pct O_2 might have improved the uranium extractions to as much as the 95 pct commonly obtained with a chemical oxidizing agent, further study of oxidation did not appear to be warranted.

Concentration of Ammonium Carbonate and Ammonium Bicarbonate: To evaluate the effect of the concentration of ammonium carbonate and ammonium bicarbonate on the dissolution of uranium, chemical analyses were run on periodic samples of the leach solution from each of the towers. In addition, because the commercial grade ammonium carbonate employed for this work was what is referred to in the literature as *ammonium carbonate of commerce* ($NH_2NH_2CO_2 \cdot NH_4HCO_3$) which decomposes in water to give variable amounts of ammonium carbonate and ammonium bicarbonate, it became necessary to run chemical analyses on the solutions prior to their addition to the repulping tank rather than relying on weighed amounts of the compounds. Fig. 6 shows the data obtained from a series of tests employing varying amounts of ammonium carbonate and ammonium bicarbonate in the leach solution.

Since only small quantities of ammonia and carbonate ions are required for combination with the uranium, then in evaluating the data two factors warrant discussion: 1) total ammonia in the solution contributing to the partial pressure of ammonia in the system and 2) the amount of bicarbonate required to prevent the build-up of hydroxyl ions. As shown by Fig. 6, total ammonia content of the solution had a marked effect on the rate of dissolution of the uranium and the maximum extraction. For example, extraction increased from 73.5 to 90 pct in 75 min when concentration of ammonia was increased from 16.3 to 46.2 g per liter. The same change boosted extraction from 86 to 93 pct after the slurry had passed through all the towers.

These data, however, do not indicate any definite effect of the ammonium bicarbonate concentration on the dissolution of uranium. In both tests, represented by Curves A and B, analyses showed that after Tower 1 the solutions contained no ammonium bicarbonate.

To determine whether stabilization of ammonium bicarbonate in solution would improve the dissolution of uranium, the test represented by Curve B was repeated with the addition of 475 cu cm CO_2 per min. Figs. 7 and 8 show that despite addition of carbon dioxide to the system, the rate of dissolution was only improved slightly and maximum extraction was only equal to that obtained in Curve A. These data show that the use of carbon dioxide would permit the use of weaker solutions, but the system appears to have no advantage where the ammonia is recovered by steam stripping.

Precipitation of Uranium from the Ammonium Carbonate Leach Solutions

Uranium can be precipitated merely by heating the solution. This decomposes the ammonium uranyl carbonate and ammonium carbonate-bicarbonate, and expels the ammonia and carbon dioxide, which are then recovered by absorption in a solution brought to a concentration satisfactory for return to the leaching system. The following equations express the chemical reactions involved:

$$(NH_4)_2CO_3(aq) + \text{heat} \rightarrow 2NH_3(g) + CO_2(g) + H_2O(l) \quad [4]$$

$$NH_4HCO_3(aq) + \text{heat} \rightarrow NH_3(g) + CO_2(g) + H_2O(l) \quad [5]$$

$$(NH_4)_4UO_2(CO_3)_3(aq) + \text{heat} \rightarrow 4NH_3(g) + CO_2(g) + UO_3 \cdot 2H_2O(s) \quad [6]$$

$$2NH_3(g) + CO_2(g) + H_2O(l) \rightarrow (NH_4)_2CO_3 \quad [7]$$

Table I. Chemical Analysis of the Ores

Ore	Assay, Pct										
	U_3O_8	V	CaO	Al_2O_3	MgO	C	CO_2	SiO_2	Fe_2O_3	S	L.O.I.
1	0.32	0.02	49.9	1.19	0.62	10.4	37.4	9.13	0.64	0.13	38.9
2	0.12	0.03	5.56	10.0	3.96	0.43	1.41	66.3	2.74	0.20	9.3
3	0.61	0.08	10.8	7.1	2.7	2.6	8.0	61.6	2.56	0.16	12.3

Table II. Chemical and Spectrographic Analysis of Precipitate

	Chemical Assay, Pct				Spectrographic Assay, Pct				
	H_2O (250°F)	L.O.I. (1742°F)	U	V	Fe	Ca	Mg	Al	SiO_2
Ore 1									
Air Dried	23.4	—	44.7	0.40	<0.01	0.05	0.01	1.3	1.3
Ignited 1742°F	—	33.2	67.3	0.50	<0.01	0.08	0.02	2.0	2.0
Ore 2									
Air Dried	6.0	—	49.7	0.25	<0.01	0.34	0.5	0.4	3.1
Ignited 1742°F	—	15.0	59.3	0.21	<0.01	0.40	0.7	0.5	3.7
Ore 3									
Air Dried	7.3	—	59.0	0.40	<0.01	0.12	0.04	1.6	1.3
Ignited 1742°F	—	17.0	72.5	0.44	<0.01	0.16	0.05	2.0	1.8

In the experimental work, steam was used to heat the solutions and to serve as a sweeping gas. In the operation of the integrated plant, air was substituted for part of the steam. Fig. 9 shows the relation between pH of the solution, time, and the amount of uranium precipitated.

The pH of the pregnant solutions varied from 9.0 to 9.2, depending on the variation in pulp density. In the test represented by the curves A and A′, the pH of the solution was not controlled by the addition of fresh solution. As the ammonia was stripped from the solution, the pH dropped, and almost complete precipitation occurred within 60 min at a pH of 7.3. As the pH dropped to below 7, the precipitate began to redissolve. At the time of maximum precipitation, the stripped solution contained 0.005 g U per liter compared with 2.0 g per liter in the pregnant solution.

To determine whether pH of the solution could be employed for operational control when the pre-

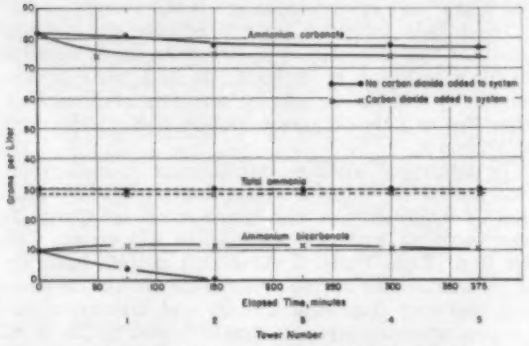


Fig. 6—The effect of concentration of ammonium carbonate and ammonium bicarbonate in the leach solution on the extraction of uranium.

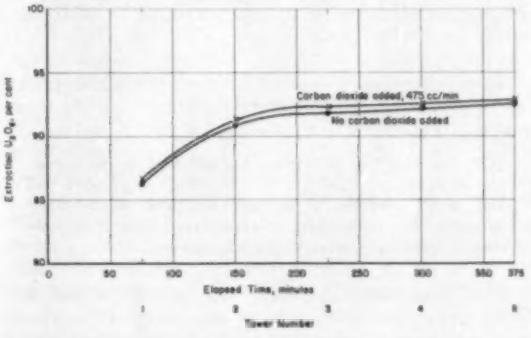


Fig. 8—The effect of the addition of carbon dioxide to the system on the extraction of uranium.

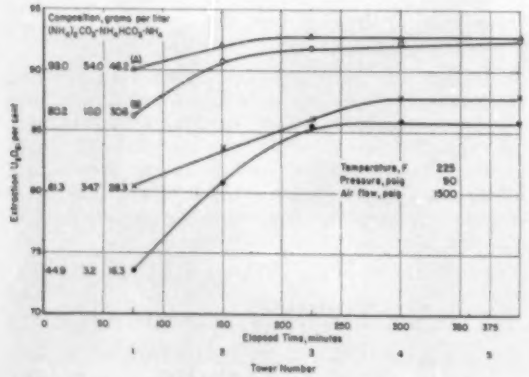


Fig. 7—Concentrations of ammonium compounds in solution with and without carbon dioxide added to the system.

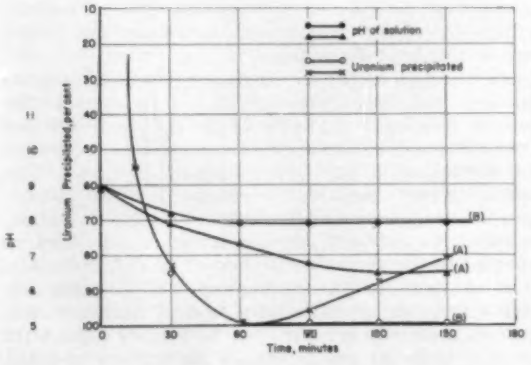


Fig. 9—The effect of time and pH of the solution on the precipitation of uranium by steam stripping.

Table III. Typical Uranium and Ammonia Balance

Uranium Balance			
Basis:			
Ore assay uranium, pct		0.52	
Feed rate, kg per hr		13.63	
Extraction uranium, pct		96.0	
Pregnant liquor assay uranium, g per liter		3.36	
Soluble uranium to CCD system, g		816	
Soluble uranium removed as samples, g		14	
Net soluble uranium to CCD system, g		802	
Distribution of Uranium in CCD System:	**Grams**		**Dist. Pct**
Thickener No. 1 overflow:			
45.4 liter per hr x 1.5 g per liter x 12 hr	789.6		98.4
Soluble loss:			
9.5 liter per hr x 0.11 g per liter x 12 hr	12.6		1.6
Total	802.2		
Distribution of Uranium in Precipitator:			
Loss in barren solution:			
50 liter per hr x 0.006 g per liter x 12 hr	3.6		0.7
Overall uranium loss:			
Soluble loss + loss in barren solution	16.2		2.3
Ammonia Balance			
Basis:			
Discharge from leaching unit, liter per hr		20.2	
Assay of pregnant liquor, NH_3, g per liter		30.0	
Total NH_3 to CCD system, g		7272	
NH_3 removed by sampling, g		143	
Net NH_3 to CCD system		7129	
Distribution of NH_3 in CCD System:	**Grams**		**Dist. Pct**
Thickener No. 1 overflow:			
45.4 liter per hr x 12.8 g per liter x 12 hr	6973.2		98.0
Soluble loss:			
9.5 liter per hr x 1.2 g per liter x 12 hr	137		
Total	7110.2		
Distribution of Ammonia in Precipitator:			
Ammonia recovery:			
35.2 liter per hr x 15.7 g per liter x 12 hr	6631.7		95.0
Loss in barren solution:			
50.0 liter per hr x 0.30 g per liter x 12 hr	180		2.6
Unaccounted loss	161.5		2.3
Total	6973.2		
Overall loss:			
Soluble loss + loss in barren solution + unaccounted loss	478.5		6.9

cipitation tower is operated on a continuous basis, a test was run maintaining the solution in the precipitation tower at pH 8 by continuously feeding the pregnant solution to the tower. The curves B and B′ show that by maintaining pH 8, the precipitation tower could be operated on a continuous basis and accomplish almost complete precipitation of the uranium. Although a pH of 7.5 appears to be a critical point with respect to redissolution of the precipitate, it is believed that the critical pH varies with each ore, depending on the salts remaining in the solution after stripping the ammonia.

At the time maximum precipitation of the uranium occurred, more than 99 pct of the ammonia and carbon dioxide had been stripped from the solution.

Composition of the Precipitate: Precipitates were produced from operation of the integrated plant on three ores. Table II gives the data obtained from chemical and spectrographic analysis of these precipitates. These data show that when the precipitates are air-dried, uranium content varies from 44.7 to 59 pct. When the precipitates are ignited at 1742°F the uranium content varies from 59.3 to 72.5 pct. As shown by the spectrographic analysis, the variation is caused primarily by solids carry-over from the countercurrent washing circuit. This contamination could have been reduced by employing a clarification filter between the thickener overflow and the precipitation tower. The uranium compound in the air-dried precipitates was identified as $UO_4 \cdot 2H_2O$ by X-ray diffraction. The ignited precipitate was identified as U_3O_8.

Operation of the Integrated Plant for the Extraction and Recovery of Uranium

Because one of the attractive features of the ammonium carbonate pressure leach is the recovery of the ammonia for return to the leaching circuit, a countercurrent decantation washing circuit and a precipitation tower were added to the system. The objective of the program was to demonstrate the uranium and ammonia recovery that could be accomplished in an integrated plant. Although it was not within the scope of this program to actually return the ammonia to the leaching circuit, absorption towers were employed to recover the ammonia from the precipitation tower. Table III gives the uranium and ammonia balance obtained from operation of the integrated plant on Ore 3.

These data show that the soluble loss of uranium from the countercurrent decantation system was 1.6 pct of the uranium in the pregnant liquor and that an additional loss of 0.7 pct was incurred by the barren solution discharged from the precipitation tower. On this basis, the recovery of uranium from Ore 3 was 95.5 pct of the uranium in the feed to the leaching system. In the case of Ores 1 and 2, where approximately 93 pct of the uranium was extracted in the leaching towers, the overall recovery of uranium was approximately 91 pct of the feed to the integrated plant.

With respect to the ammonia recovery system, the data show that the ammonia lost with the discharge from the countercurrent decantation washing system was equivalent to 1.67 lb NH_3 per ton of dry feed, and that the total loss of ammonia from the system including the loss with the barren solution and the unaccountable loss was equivalent to 5.85 lb per ton of dry feed to the integrated plant.

Conclusions

The data obtained from this study have demonstrated that the ammonium carbonate pressure leach is a technically attractive method for extraction of uranium from high-lime ores.

As in the case of other processes developed for the extraction of uranium from domestic ores, the process does not appear applicable to high gypsum or high vanadium ores. On the other hand, with its low reagent cost for precipitation and the recovery of substantially all of the ammonia, the process appears to have advantage over other alkaline leach processes. In addition, because of these same factors, it is probably competitive with an acid leach of medium-lime ores. At the same time, because an acid leach usually will extract about 98 pct of the uranium from low-lime ores, the acid leach still appears to maintain its advantage. The advantages and disadvantages of the several methods available for extracting uranium from low-grade ores are such that a careful economic comparison should be made for each ore being considered.

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[2] F. A. Forward and J. Halpern: *Developments in the Carbonate Processing of Uranium Ores, AIME Trans.*, 1954, vol. 200, p. 1408; Journal of Metals, December 1954.

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THE SEARCH FOR LOWER COSTS
— PROBING THE PROCESSES

Solvent Extraction of Uranium at Shiprock, N. M.

By W. C. Hazen

A. V. Henrickson

URANIUM plant operations of the Kerr-McGee Oil Industries at Shiprock, N. M., began in December 1954. As originally designed, the plant treated Plateau carnotite ores by the acid cure process, which dissolved both uranium and vanadium minerals.

After 16 hr of acid curing, the ore was conveyed to an agitator and leached for 2 hr in acid liquor at a pH of 1.0. The leach pulp was then separated at 100 mesh in a classifier, the sands continuing through a washing classifier circuit and the slimes going to a countercurrent decantation system of four thickeners.

Leach liquor containing the uranium and vanadium values was passed through a column ion exchange plant for uranium recovery, and the barren liquors were further processed by a precipitation method for vanadium recovery.

In mid-1955 an expansion of the mill was planned to double the original tonnage. It was also decided to alter the flowsheet and substitute a 16-hr agitation leach for the acid cure process, since with the new ores vanadium recovery was no longer of importance. Agitation leaching would also permit reduced acid consumption and less labor.

Since more ore was to be handled, the expansion had to include additional equipment for recovering uranium from the larger volume of leach liquor produced. The company had been studying solvent extraction in the laboratory for some time and this seemed a natural place for its application. Before expansion to the new process was decided upon, however, experimental work was undertaken on a larger scale. Tests were made in 50,000-gal wooden tanks that had previously been used for vanadium precipitation. A batch of feed liquor was pumped into one of the tanks and adjusted to the proper voltage and pH. After the solvent was added, the whole mixture was agitated 10 min and allowed to stand 1 hr to separate into its two phases. The uranium-loaded solvent was then skimmed from the top of the aqueous phase, stripped with sodium carbonate solution, and returned for a second extraction.

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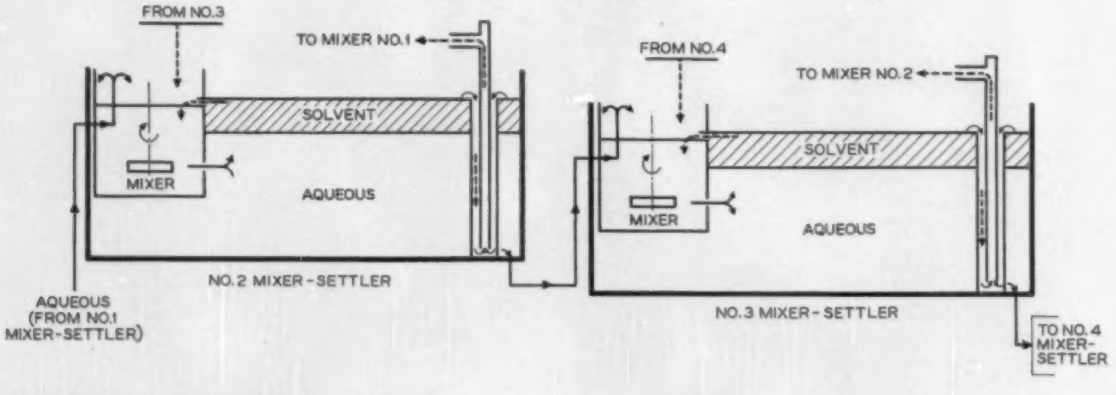
EXTRACTION CIRCUIT
MIXER-SETTLER ARRANGEMENT



By repeating this stepwise extraction a number of times it was possible to lower the uranium assay in the aqueous liquor to the discard level. The operation was analogous to batch experiments in the laboratory and suffered the drawback of batch operation, but even with this makeshift experimental setup it was possible to add to plant output significantly, since each batch contained the solution from about 75 tons of ore. This experimental procedure was incorporated as part of production, and from July 1955 until September 1956 liquor from many thousands of tons of ore was treated.

A continuous countercurrent solvent extraction plant built in the summer of 1956 was placed in operation in September, at which time the batch operation was discontinued.

Process: The process in the new plant utilizes di-2-ethyl hexyl phosphoric acid and tributyl phosphate dissolved in a high flash-point kerosene to extract uranium from the acid leach liquor. The uranium-laden solvent is stripped with 10 pct sodium carbonate solution and the barren solvent is returned to the extractor. The uranium-bearing carbonate liquor from the stripper is acidified and the uranium precipitated with ammonia or magnesia.

In determining the particular solvent to use, consideration was given to the amines, the monoalkyl phosphates, and di-2-ethyl hexyl phosphoric acid. Of the many possibilities, the Oak Ridge DAPEX* process, using di-2-ethyl hexyl phosphoric acid, had one outstanding virtue—the solvent was already available in commercial amounts at an established price. All other solvents were *potentially* available only in experimental quantities. Although the DAPEX process has other qualifications for the Shiprock feed liquors, solvent availability was the decisive factor.

* This solvent process was developed in the Oak Ridge National Laboratory, Raw Materials Chemistry Division, by the group headed by K. B. Brown. Much of their work has been published in declassified form and is now available.[1]

In the application of the process at Shiprock no significant deviations were found from the data that have been published. It is a tribute to the competence of the Oak Ridge work that the estimates made there from laboratory tests have been verified so closely by actual experience in a production plant.

Reduction Circuit: In the DAPEX process the acid liquor must be relatively free of ferric iron, since this element extracts to some extent under the conditions used for uranium recovery.

Reduction of ferric iron to ferrous is accomplished by passing the acid liquor from the thickener overflow through a bed of scrap steel shavings purchased from machining operations. These steel shavings are loosely packed to a depth of 6 ft in a 5-ft diam wooden tank having a false bottom. The solution flows into the bottom of this tank and is reduced as it rises through the steel shavings.

By insuring that there are always enough shavings and that fine material does not clog the tank and cause channeling, it is possible to reduce ferric iron easily and cheaply. It has been found by experience that if the liquors are reduced to an electromotive force between 175 and 300 mv (negative), substantially no iron is picked up in the extraction circuit.

Extraction Circuit: The extraction section is composed of four mixer settlers arranged in a cluster. The mixer settlers differ in elevation from one unit to the next by 12 in., so that the aqueous phase flows by gravity, while solvent is transferred uphill from one stage to the next by air lifts.

The extraction unit is designed for an aqueous flow of 120 gpm, the liquor produced from 350 tpd. Maximum solvent flow at this capacity was to be 40 gpm.

Each mixer-settler stage is comprised of one wooden stave tank, 6 ft deep and 16 ft diam, and a 4x4-ft stainless steel mixing tank placed on legs against the wall inside the settler. The major purpose of placing the mixers inside the settlers was to facilitate piping, since connections between mixer and settler are achieved by holes cut in the wall of the stainless mixer tank.

Agitation in the mixers is provided by 18-in. diam turbomixers with V-belt drives. Two of the four mixers are operating at 150 rpm and two at 200 rpm. No decision has been reached as to which speed is better.

The air lifts for advancing the organic phase are constructed of polyvinyl chloride plastic pipe and are set in each settler inside a plastic pipe *boot* into which the solvent overflows. The total height of organic in any settler can be raised or lowered easily by changing the position of this plastic boot.

The aqueous phase flows from one settler into the succeeding mixer through a 6-in. diam flexible Carlon hose. Both aqueous and solvent flow are measured by recording Rotometers.

Stripping Circuit: The stripping circuit is composed of a two-stage mixer-settler. In this case the mixers are outside the settlers and connected to them by piping. Th solvent flows by gravity, while the sodium carbonate stripping solution is advanced countercurrent with air lifts. All equipment in this part of the plant is built of mild steel, since it has adequate corrosion resistance.

Mixers are the same size as those used in the extraction circuit—4x4 ft equipped with 18-in. diam turbomixers. Steam coils made of three turns of 2-in. pipe are welded in each mixer.

The settlers are 8-ft diam cone-bottom tanks with internal launders for solvent overflow. Cone-bottom settlers were used because of the presence of small amounts of precipitates of titanium and iron hydroxides, or their basic carbonates, which are formed during stripping.

In operation of the stripping unit the pregnant organic solvent from the first extraction unit settler is pumped by a centrifugal pump to mixer No. 1, where it is agitated with the advancing carbonate liquor. Solution from the mixer flows by gravity to settler No. 1, where the phases separate, the organic overflowing by gravity to mixer No. 2 and the carbonate liquor, which contains some suspended solids, flowing via an underflow leg to a pump and storage tank.

This pregnant carbonate liquor is pumped through a plate and frame press to remove suspended solids and the clear filtrate is sent to the uranium precipitation circuit.

The 10 pct sodium carbonate solution is made up in a 5000-gal agitated batch tank, from which it flows by gravity through a recording Rotometer to the stripping circuit.

Precipitation: Uranium from pregnant carbonate solutions is recoverable by either of two general methods: 1) caustic precipitation or 2) destruction of carbonate with acid, followed by precipitation of uranium as yellow cake with ammonia or magnesia.

Caustic precipitation of uranium from carbonate strip liquors, followed by recycling of the carbonate, was used in some of the batch runs at Shiprock, but

had no particular merit over the acid method because of local plant conditions. Shiprock has an ion exchange plant that produces a uranium-bearing acid solution and a solvent extraction plant that produces the sodium carbonate solution. It is obvious that some reagent economy can be effected by mixing these two streams and allowing them to neutralize each other and then precipitating the uranium oxide product from this mixed solution. This is the practice that has been followed for several months.

In some respects the complication in operating procedures introduced by mixing these two streams has perhaps outweighed the reagent economy, and consideration is now being given to the advantages of precipitating the ion exchange eluate and the strip carbonate liquors independently.

Operating Results

Operation of this plant has turned out to be very straightforward and simple. One operator per shift runs the extraction and stripping. A set of typical operating conditions is given below:

Aqueous flow	100 gpm
Solvent flow	20 gpm
Aqueous feed analysis:	
electromotive force	−300 mv
pH	1.3
Temperature	90°F
U_3O_8 gpl	1.4
V_2O_5 gpl	0.6
Sodium carbonate to strippers	2.5 gpm
Stripping temperature	110°F

For long periods of time it has been possible to operate the solvent extraction unit with a tailing solution assay averaging less than 0.005 g U_3O_8 per liter, corresponding to better than 99.7 pct recovered. At a period of stable operations samples have been taken through the entire system and analyzed for uranium content. A typical set of such analyses is shown below:

Circuit		Organic Phase U_3O_8 Gpl	Aqueous Phase U_3O_8 Gpl
Extractor	No. 1	8.95	1.27
	No. 2	7.92	0.43
	No. 3	2.29	0.023
	No. 4	0.47	0.002
Stripper	No. 1	0.37	55.6
	No. 2	0.010	2.6

Consumption of reagents in this plant has been close to that predicted from laboratory work:

Iron for reduction	0.75 lb per lb U_3O_8
Sodium carbonate	2.0 lb per lb U_3O_8
Solvent loss	0.5 gal per 1000 gal of aqueous treated
Sulfuric acid to destroy carbonate	1.6 lb per lb U_3O_8
Ammonia for precipitation	0.15 lb per lb U_3O_8

The amount of iron required for reduction is naturally a function of the properties of the leach solution—primarily the ferric iron content. This would be one of the major considerations in the choice of a solvent system, since amine solvents are not so sensitive to the presence of ferric iron as phosphates are. At Shiprock, however, steel shavings for reduction are delivered at $22.00 per ton, so the cost per pound of product for this reduction step is low.

Soda ash consumption can be reduced nearly to theoretical amounts but this will depend, to some extent, on the titanium content of the feed liquor and on the care used in operating control.

Solvent losses given above were determined for the first 10 million gal of feed liquor treated in the plant. This loss is made up of two components. The first is the actual solubility of the solvent in the aqueous phase, and the second is the loss of organic carried out by the raffinate as small droplets. The solubility factor is small. Measurements of entrainment loss show that it accounts for at least half the total solvent loss.

Undoubtedly a trap tank would prevent some of this entrainment loss. Another possibility would be to operate the mixers with the organic phase continuous by recycling solvent from the settlers back to the mixers. In experiments this has been found to decrease entrainment of solvent. Both alternatives, the trap tank and continuous organic phase in the mixers, are under consideration for the Shiprock installation.

The cost given for sulfuric acid required to destroy the carbonate and the ammonia required for precipitation of yellow cake are for the amounts that would be necessary if the acid eluate from ion exchange were not mixed with the carbonate strip liquor.

The use of a high flash-point kerosene as a diluent has been of great aid in processing because of the decreased fire hazard. The material used at Shiprock is sold under the trade name Napoleum 470 and is produced by the company's Deep Rock Oil Div. It has a flash point of 160°F compared to 105° for ordinary kerosene as available in the Shiprock area. The price is 18½¢ per gal delivered at Shiprock, but the relief from fire danger is well worth the added cost.

The problem of emulsion formation is always raised in discussion of solvent extraction. At Shiprock the only problem of this sort has resulted from the introduction of graphite into the system by dissolution of steel shavings. There is no clarification filter on the feed liquor system and graphite freed from the iron is carried into the first stage extractor, where it transfers into the organic layer in the No. 1 mixer. In the plant design provision was made for removing this solid material by filtering the solvent at periodic intervals, but it has never been necessary to use this cleaning equipment because of an unforeseen but fortunate circumstance. The graphite-stabilized clods of emulsion, which have been called seaweed, float to the surface of the solvent in the settler instead of remaining at the interface as had been anticipated. These clods pass over the organic overflow and into the sodium carbonate stripping circuit. In the first stripping mixer this graphite-stabilized emulsion is broken and the solvent is released while the solids drop out with the solid hydroxides and are removed in the byproduct filter. In time this gummy material can cause trouble by plugging pipelines and pumps, but a clarification filter to be installed on the feed liquor will eliminate the trouble at the source. In the meantime no problems have been caused by the presence of these seaweed clods.

Flow rates have been easy to maintain and control at any desired ratio. Control of interface levels has turned out to be no problem at all. The level of the aqueous phase in each settler is, of course, set by the height of the weir on the discharge pipe from that settler. The elevations of these weirs were set by calculation when the plant was designed and have not been altered.

The design of the settlers includes enough freeboard so that if the organic should stop flowing for any reason, such as air lift failure, there is room for accumulation of the entire solvent excess in any one settling tank. It is impossible to spill solvent over the top of a settler.

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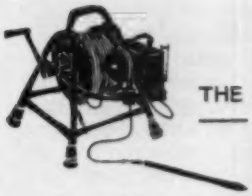

THE SEARCH FOR LOWER COSTS
— PROBING THE PROCESSES

Solvent Extraction Newcomer to the Colorado Plateau

by A. M. Ross

DURING the past year the uranium milling industry has seen the installation and initial operation of solvent extraction circuits in the Climax Uranium Co. mill at Grand Junction, Colo.; the Kerr-McGee Oil Industries mill at Shiprock, N. M.; and the AEC pilot plant at Grand Junction, operated by National Lead Co. Inc. The Vitro Uranium Co. mill in Salt Lake City is converting to solvent extraction, and the new Union Carbide Nuclear Co. mill to be constructed at Rifle, Colo., will also employ this method. Solvent extraction circuits will be incorporated in two mills now under construction —the Texas Zinc Minerals Co. mill at Mexican Hat, Utah, and the Gunnison Mining Co. mill at Gunnison, Colo. In Canada the expansion of the Eldorado mill at Port Radium includes installation of a solvent extraction circuit.

Solvent Extraction Process: In simplest terms, the organic solvent is mixed with leach liquor and then the organic and aqueous phases are allowed to separate. By this contact the solvent selectively extracts uranium from the liquor, leaving a raffinate, or barren leach liquor, which may be discarded. The pregnant solvent is stripped of its uranium by contact with a stripping solution, such as aqueous sodium carbonate, which has a greater affinity for uranium than the solvent does. The barren solvent from the stripping step is available for further leach liquor extraction, and the pregnant stripping solution, which usually contains 30 to 60 g U_3O_8 per liter, is ready for precipitation of a final product, or uranium concentrate.

Advantages and Disadvantages: Solvent extraction has excited great interest in the uranium milling industry because it offers several advantages over competing acid processes such as ion exchange:

Simplicity and Flexibility. Solvent extraction is a straightforward process with the simplicity and flexibility of a liquid-liquid system, rather than the solid-liquid system of ion exchange.

Ease of Control. Solvent extraction permits true continuous countercurrent operation, which in turn lowers operating costs. Because stream compositions are constant, and independent of cycle time, the process is very easily controlled.

Decreased Effect of Impurities. Solvent extraction can be used on liquors that are not amenable to ion exchange because they contain large quantities of certain impurities such as molybdenum or organic matter. Also, the method is not restricted to sparkling clear feed solutions (except when amine solvents are used) and is currently being applied commercially to thickener overflow liquors turbid with minor amounts of slimes.

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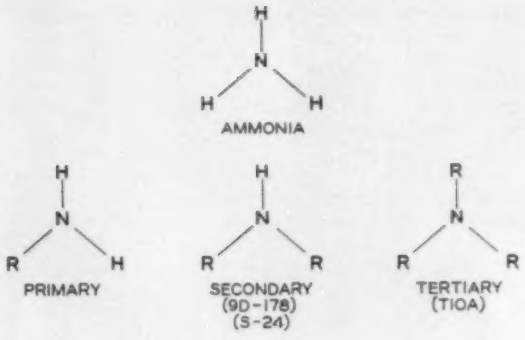
Solvent Extraction Flowsheet



Amines

Versatility. Solvent extraction is more versatile than ion exchange. A wide variety of solvents are available from which to select the solvent most suitable for individual problems. For example, acid leach liquors containing significant quantities of chloride ion, as from a salt roast process, cannot be treated by ion exchange. Neither can they be treated by amine solvents. However, any of the alkyl phosphate solvents will extract uranium in the presence of chloride without difficulty.

Byproduct Recovery. Byproducts are readily recovered with solvent extraction. The possibility of recovering such byproducts as vanadium, molybdenum, or thorium by solvent extraction is well known.

Possibility of Reactor-Grade Purity. There is an excellent possibility that with certain modifications solvent extraction can be used to produce a uranium oxide or uranium fluoride of reactor-grade purity at the mill.

Solvent extraction also has some disadvantages:

Solubility and Entrainment Losses. All solvents have a certain aqueous solubility and there is a finite entrainment loss of solvent to the aqueous phase. These losses are proportional to the amount of leach liquor processed and are independent of the amount of uranium processed. Therefore the solvent losses per pound of recovered U_3O_8 become higher as the grade of the liquor decreases, and with low grade liquors solvent losses per pound of U_3O_8 can be high. On the other hand, the cost of ion exchange, within wide limits, is not materially affected by liquor grade.

Unsuitability for Pulps. Although the results of development work appear encouraging, solvent extraction is not yet practical for recovery of uranium from pulps because of excessive entrainment losses. Only in the special case of dilute slurries very rich in uranium can solvent extraction be used successfully. On the other hand, ion exchange is well known to be applicable to pulps, as evidenced by the extensive use of the resin-in-pulp process.

Unsuitability for Carbonate Systems. No solvent is commercially available that is economically applicable to the recovery of uranium from carbonate leach liquors.

Possibility of Emulsion Formation. In certain cases physical problems may be encountered, such as emulsion formation or solids precipitation. These can usually be remedied or eliminated by proper equipment design and operation, although in some instances the solvent must be modified.

Uranium Extractants: Many solvents have been recommended for extracting uranium from acid leach liquors. Those that are commercially available may be divided into two categories, amines and phosphoric acid esters.

The amines may be considered derivatives of ammonia. When one hydrogen is replaced with a carbon chain (that is, an alkyl group) the amine is primary, when two hydrogens are replaced the amine is secondary, and when three are replaced the amine is tertiary. The alkyl amines recommended for uranium extraction have thus far been limited to the secondary and tertiary amines. The primary amines are generally nonselective and exhibit excessive aqueous solubility.

Of the alkyl amines recommended as uranium extractants, three are commercially available: TIOA, or triisooctylamine; Amine S-24; and Amine 9D-178. All three are excellent products and have been prepared thus far in pilot quantities at a projected price of about $1.25 per lb in large quantities. The first two are manufactured by Carbide & Carbon Chemicals Corp. and the third by Rohm & Haas Co.

Two mills now under construction will employ amine solvents, the Texas Zinc Minerals mill at Mexican Hat, Utah, and the Eldorado mill at Port Radium in Canada. Both will use the Rohm & Haas Amine 9D-178, as this was the first suitable amine available commercially for solvent testing and development.

When used as a uranium solvent, the amine is dissolved in a hydrocarbon diluent such as kerosene. A typical solvent contains about 5 pct by volume of amine in kerosene. Normally the solvent also contains a few percent of a long-chain alcohol to increase the rate of phase disengagement and to lessen any tendency toward third phase formation.

The organophosphorus extractants are usually esters of phosphoric acid. When one hydrogen is replaced by an alkyl group, the compound is a monoalkyl phosphoric acid; when two hydrogens are replaced, the compound is a dialkyl phosphoric acid; and when all three hydrogens are replaced, the compound is a trialkyl phosphate.

An example of a monoalkyl phosphoric acid is DDPA, or dodecylphosphoric acid. EHPA, or di-(2-ethylhexyl)phosphoric acid, is an example of dialkyl phosphoric acid, and TBP, or tributyl phosphate, is an example of trialkyl phosphate. TBP is used in uranium refineries to extract uranium from nitric acid solutions but is not applicable to sulfuric acid solutions.

Both the Climax mill at Grand Junction, Colo., and the Kerr-McGee mill at Shiprock, N. M., use EHPA, which is manufactured by Carbide & Carbon Chemicals Corp. and sold at about $1.00 per lb.

A similar product may soon be available from Eastman Chemical Products Inc. in Kingsport, Tenn.

Vitro Uranium Co. in Salt Lake City, now converting to solvent extraction, plans to manufacture its own DDPA by reacting dodecyl alcohol with phosphorus pentoxide.

Like the amines, the alkyl phosphate solvents are used with kerosene as the diluent. A typical solvent contains 3 to 5 pct by volume of phosphate ester in kerosene. Also, to prevent third phase formation during stripping, the solvent should contain a few percent of tributylphosphate or a long chain alcohol.

Amines Vs Phosphates: The principal advantage of alkyl amines as compared with the alkyl phosphates is their selectivity toward uranium. Only molybdenum is extracted along with uranium; almost all other elements remain unextracted. Molybdenum is easily stripped from the solvent, and stripping conditions can be simply regulated to allow the quantitative separation and recovery of both the uranium and the molybdenum. Alkyl phosphates are much less selective and extract significant quantities of several elements. Fortunately, in Plateau leach liquors most of these elements do not occur in sufficient concentration to create a problem.

However, ferric iron is readily extracted by alkyl phosphates, although ferrous iron is not. When alkyl phosphate solvents are used, any ferric iron in the liquor must be reduced to the ferrous state. If there is much ferric iron in the liquor to be treated, cost of reduction becomes an important factor.

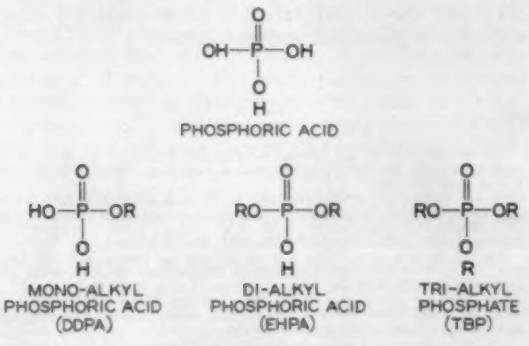
Because of higher selectivity the amines, particularly tertiary amines, give excellent separation of uranium from thorium, whereas the phosphates do not give as clean a uranium-thorium separation.

Amines are not applicable to turbid solutions because they adsorb on solids, creating excessive solvent losses. Alkyl phosphates are not affected by minor amounts of solids.

Comparison of Solvents

	Amines	Phosphates
Selectivity	Excellent	Fair to good
Applicability to turbid solutions	Poor	Excellent
Applicability to Cl^- or NO_3^- solutions	Poor	Excellent
Flexibility of stripping	Excellent	Fair

Amines, like ion exchange resins, cannot be used to treat liquors containing significant quantities of chloride or nitrate. Alkyl phosphates, on the other hand, are not inhibited by the presence of chloride or nitrate and should be used in extracting a liquor that is prepared from a salt-roasted ore. At the Climax mill in Grand Junction salt roasting is followed by solvent extraction with EHPA.



Phosphoric Acid Esters

The amines offer an advantage over the alkyl phosphate extractants in that uranium can be stripped from an amine by any of several different stripping agents. Sodium chloride, ammonium chloride, sodium nitrate, or sodium carbonate will efficiently strip uranium from the amines. On the other hand, stripping of the alkyl phosphates is limited to sodium carbonate. Concentrated hydrochloric acid will also strip uranium from alkyl phosphates but not nearly as efficiently as the carbonate.

This flexibility is especially valuable in byproduct recovery of extracted molybdenum. Both uranium and molybdenum are extracted by the amine. When the uranium is stripped with acidified chloride, the molybdenum remains in the solvent. The molybdenum is then stripped with ammonia or sodium carbonate in a second operation.

Solvent Extraction Costs: The costs involved in solvent extraction are currently being studied at the AEC pilot plant in Grand Junction. Liquors from several ores have been processed at the plant, and several solvents have been evaluated and operating costs obtained.

An accompanying table shows the pilot plant reagent consumption data recently obtained during shakedown tests of a newly installed solvent extraction circuit, now being used to investigate solvent extraction of lignite leach liquors. The ore feed came from the White Canyon district of Utah, and the active solvent was triisooctylamine. The ore, which averaged 0.15 pct U_3O_8, was leached with 150 lb of H_2SO_4 per ton, and the clarified leach liquor from the CCD circuit averaged 0.50 g U_3O_8 per liter. The dissolved uranium was extracted, in four mixer-settler stages, into a solvent containing 4 pct TIOA and 5 pct primary decyl alcohol. Extraction efficiency was greater than 99.9 pct (less than 0.0005 g U_3O_8 per liter of raffinate). The solvent was stripped with 1 molar sodium chloride acidified to pH 1.2 with sulfuric acid, and the resulting strip liquor contained 25 g U_3O_8 per liter. The final product, obtained by MgO-precipitation of the strip liquor, assayed 80 pct U_3O_8 and met all concentrate specifications.

As shown in the table, total actual reagent cost (FOB Grand Junction) was 18.4¢ per lb of recovered U_3O_8. The cost shown for TIOA is based on the development price of $2.00 per lb. The TIOA cost shown in parentheses is for the projected commercial price of $1.25 per lb. Costs shown for NaCl and MgO are those obtained during the actual shakedown run. Since excess reagents were employed during this run to provide a wide margin of operational safety, the costs are somewhat high. The NaCl and MgO costs shown in parentheses should be readily achieved by using a reduced but ample reagent excess. The parenthetical costs lead to a total reagent cost of 13.2¢ per lb of recovered U_3O_8.

Reagent Consumption

Reagent	Consumption Per Pound of Recovered U_3O_8	Cost Per Pound of Recovered U_3O_8, ¢
TIOA	0.0082 gal	11.5 (7.4)
Decyl alcohol	0.0035 gal	0.7
Kerosene	0.058 gal	0.9
NaCl	2.57 lb	3.0 (2.3)
H_2SO_4	0.22 lb	0.3
MgO	0.37 lb	2.0 (1.6)
	Total	18.4 (13.2)

Whether the total cost is 13¢ or 18¢ solvent losses constitute the major source of reagent costs. In this case they amount to 70 pct of the total cost. Since solvent losses are directly proportional to the volume of leach liquor treated, serious consideration should be given to ways and means of decreasing this volume, that is, of increasing the liquor grade. Increasing the liquor grade would correspondingly decrease solvent losses per pound of U_3O_8. This consideration could influence the selection of filters over thickeners in the liquid-solid separation sections of solvent extraction plants.

Solvent Extraction Developments: In addition to the work of the Grand Junction pilot plant, extensive solvent extraction studies are also being performed at the AEC Raw Materials Development Laboratory, operated in Winchester, Mass., by the National Lead Co., Inc. It is here that newly available solvents and solvent processes are tested and evaluated. Here, also, the amenability of ores to solvent extraction is investigated on a laboratory scale.

During the past two years a great deal of experimental and development work has been carried out on solvent extraction processes at the Winchester Laboratory. These processes include: 1) the Eluex process, in which uranium is recovered from ion exchange eluates by solvent extraction; 2) the lignite treatment process, in which solvent extraction is used to recover uranium from lignites; and 3) the solvent leaching process, in which uranium is recovered by direct leaching of the ore with solvent. The first process has been successfully demonstrated in the Grand Junction pilot plant, the second process is being piloted now, and the final process is in development at the Winchester laboratory.

Because of its many attractive features, solvent extraction is being widely publicized and heralded by many as a new process to replace ion exchange. This is not the case. Each has its place in uranium milling. Solvent extraction is particularly attractive for the treatment of high grade liquors, whereas ion exchange is superior for low grade liquors.

Naturally, there is an area of overlapping where the processes are competitive, and most Plateau liquors lie in this area. In some cases, relative costs may be so close that the choice between processes will ultimately be decided on the basis of past experience and personal preference as much as for any other reason. The AEC Winchester laboratory and the Grand Junction pilot plant are continuing to examine both processes and to evaluate their relative merits and costs.

Historical Background

In preparing this paper, the author has drawn freely from his own experience, conversations with others, and available literature. Although it has been beyond the scope of this paper to supply detailed references regarding the many ramifications of uranium solvent extraction, it would perhaps be of interest to describe briefly the history of the development of solvent extraction processes for the recovery of uranium from its ores.

The use of organophosphates for uranium recovery originated in 1947 at Iowa State College[1], where it was found that tributyl phosphate, or TBP, will extract uranium from nitric acid solutions. In 1949 workers at the Hanford Works found that the hydrolysis products of TBP, namely the mono- and di-butyl phosphoric acids, exhibit enhanced extractive properties toward uranium.[2] Concurrently, the University of California radiation laboratory was obtaining similar results[3] and carried out a brief program into the relative effectiveness of a large number of mono- and di-alkyl phosphoric acids as uranium extractants.[4]

In 1951 workers at Dow Chemical Co. in Pittsburg, Calif., reported several mono- and di-alkyl phosphoric acids as suitable for extraction of uranium from commercial phosphoric acid.[5] These early studies by Dow led to development of the present solvent extraction process for recovery of uranium from Florida phosphate liquors.[6] Subsequently, the Dow workers continued their studies on alkyl phosphoric acids, and in cooperation with the U. S. Bureau of Mines at Salt Lake City they developed a process employing dodecylphosphoric acid, or DDPA, to extract uranium from sulfuric acid leach liquors.[7]

In 1951 an extensive program was initiated at the Oak Ridge National Laboratory to study organic reagents as extractants for uranium.[8] Literally hundreds of reagents were screened and evaluated. This program included not only organophosphorus compounds but organonitrogen compounds as well. The work with the organophosphorus compounds led to the process employing di(2-ethylhexyl)phosphoric acid, or EHPA, to extract uranium from sulfate leach liquors.[9] The work with the organonitrogen compounds led to the process employing amines to extract uranium from sulfate liquors.[10]

The application of amines to uranium recovery stems from their strong analogy to anion exchange resins, and indeed, the amines are frequently termed liquid anion exchangers.[11] It is interesting to note that the first reported use of amines for the solvent extraction of uranium was made at Battelle Memorial Institute in 1948, in a study related to the recovery of uranium from superphosphate solutions.[12]

Acknowledgment

The author expresses sincere appreciation to J. S. Breitenstein and the staffs of the Winchester laboratory and the Grand Junction pilot plant for many valuable suggestions and comments.

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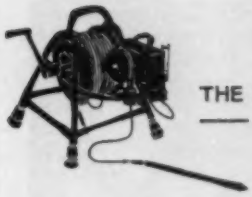

THE SEARCH FOR LOWER COSTS
—— PROBING THE PROCESSES

Continuous Countercurrent Ion Exchange in Hydrometallurgical Separators

by Clement K. Chase

ION exchange recovery of uranium has been proved successful in many operating plants in various parts of the world. First used in column plants processing clear liquors, ion exchange has more recently been applied in basket resin-in-pulp systems. A logical further development is the application of truly continuous processing techniques to the ion exchange recovery of metals, since previous systems have been semicontinuous at best.

Column ion exchange is a valuable technique and has been used extensively in South Africa and elsewhere. However, it requires clear liquors. To produce these clear liquors, considerable investment in filter plant and clarification equipment is necessary. In the cases where it is very difficult or impossible to produce clarified liquors, column ion exchange is not so useful. Moreover, some liquors suffer from post-precipitation after clarification, which can become a serious problem.

In column ion exchange, the liquor downflow through the resin bed embodies a principle of general utility: the resin at the top of the bed, already partially or almost completely loaded, is in contact with the incoming liquor highest in grade in the exchangeable ion. As the liquor goes down through the bed and becomes progressively depleted, it is in contact with resin less and less loaded and, therefore, more and more avid for the ion of interest. Finally, near the bottom of the bed, the nearly depleted solution is in contact with unloaded resin. The ion is thus almost completely removed.

In batch ion exchange there is no such desirable gradient. The ions remaining in solution come to equilibrium with those on the resin, and removal is far from complete in one stage. There must be a number of stages, as in the basket resin-in-pulp system.

Basket resin-in-pulp has been applied recently in five operating mills in the Colorado Plateau region after its demonstration in the Grand Junction pilot plant under the auspices of AEC. This process avoids the necessity of producing clarified liquors. The investment in a basket resin-in-pulp plant is considerably higher, however, than for some other systems, notably solvent extraction.

Solvent extraction is an attractive process, of low capital cost, but it too has limitations. It has not been applied successfully to alkaline leach slurries, and in some cases impurities in the ore cause difficulties. Like column ion exchange, therefore, it requires clarification liquors.

Although there is considerable background of solvent extraction application in recovery of uranium feed materials, its practical application in the field of extractive metallurgy is just beginning. Any technique that combines the low capital costs of solvent extraction with the well established ion exchange technology will be in a favorable position.

During the past eight years uranium has been a high-cost metal, produced inefficiently and at high reagent cost. Recent advances in metallurgical procedure—among them ion exchange—have reduced processing costs drastically, and economy of processing is due to become more and more important. Price for the metal from ore refining plants was once $15.00 or more per lb of U_3O_8, by negotiated contract with the AEC. New AEC contracts will probably buy concentrates at about $8.00 per lb.

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Outdoor grinding, leaching, and sand-slime separation section. Of necessity, slime separation was carried out by batch decantation.

This indicates the need for greater efficiency and lower equipment costs. With lowered prices, there may be an economic reason for not striving for the utmost in recovery.

The forward-looking attitude of the AEC has modernized the uranium industry overnight, and many of these developments can be applied to fields other than uranium.

It is the task of the hydrometallurgical engineers to provide new tools and new techniques. Such new tools have become numerous enough to make it a pleasant assignment to select the one best adapted to any particular situation. There is, of course, no general rule for success in all hydrometallurgical problems. Blanket statements that any one process is best for any situation may be evidence of technical irresponsibility, since the overall process must always be considered, with its corrosion, materials handling, precipitation, and poison problems. Thorough evaluation must be made of the different methods as applied to a particular ore. A valuable new tool has been added, however, when it is demonstrated that the thoroughly proven ion exchange method can be applied in continuous processing to slurries. Capital investment requirements should be at least as low as for other processes currently being considered.

Ion exchange has previously been known as a process best tailored to recovering metals of low concentration. Continuous countercurrent resin-slurry operation opens the door to the treatment of bulk metals. There have been men with the foresight to see this technique coming. Such a man is T. G. Chapman, pioneer in the concept of extracting dissolved values from pulps in his work on the cyanide-charcoal process for recovery of gold. The Golden Cycle mill is an example of a successful operation in adsorbing precious metal values from slurries which antedates the commercial resin-in-pulp uranium plants.

To return to uranium, there are five mills on the Colorado Plateau using the basket resin-in-pulp process and several more scheduled. The technical staffs of these mills were faced with a choice of column or basket resin-in-pulp operation. They believed that although the basket resin-in-pulp process might not be optimum, costs were excellent in comparison to previous methods. They chose it and they are not displeased.

Basket resin-in-pulp has mechanical and metallurgical limitations, nevertheless. And now a technique has been developed that will remove most of these limitations and offer new advantages. This is the continuous countercurrent operation of a resin-slurry ion exchange system.

Continuous countercurrent ion exchange has been considered by many major companies in the metallurgical industries, and there have been many ingenious proposals for accomplishing this goal, but commercial operations embodying this process have been as scarce as 0.00 tailings assays.

Considerable work has been done on both continuous ion exchange and solvent extraction. Techmanix Corp. has worked extensively on these processes. Infilco Inc. has had vast experience in clarification of water and wastes as well as in fixed bed ion exchange. Two years ago Infilco started developing a continuous countercurrent resin-slurry ion exchange process using a combination of liquid-solids separation and ion exchange techniques. Recently Techmanix and Infilco have cooperated in pilot plant studies on uranium recovery from leach pulps by continuous countercurrent ion exchange, using the facilities of Infilco's Tucson, Ariz., laboratories.

The Infilco apparatus used in these pilot studies employs many of the principles of the Aero-Accelator plant. The Aero-Accelator unit is a machine of proven design and world-wide usage in waste and water treatment. The present process demonstrates the adaptation of known hydraulic techniques to a new field, with modifications necessary for carrying out resin-slurry operations without appreciable resin attrition.

Results of pilot plant operations on uranium pulp have been excellent. Several resin-slurry applications now appear to be economically and technically feasible, using processes made possible by the Infilco continuous countercurrent ion exchange apparatus. However, in view of the numerous variables that must be investigated in each instance the necessity for adequate pilot studies for various applications will be understood.

The process seems equally applicable to hydrometallurgical recovery of most other metals, many of which are overdue for improvements in method. Recovery of copper and zinc, for instance, has changed little in the last quarter century. Many oxidized copper and zinc deposits are largely untouched and the oxidized zones of many operating mines are not too profitable under present metallurgical practice. Techmanix has felt that successful treatment of these oxidized ores is one of the major challenges in present day metallurgy.

Returning now to the pilot plant scale operations on uranium extraction, eight tons of ore were obtained from Charles A. Steen's Mi Vida mine near Moab, Utah. It arrived crushed to approximately 10 mesh, assaying as follows: U_3O_8, 0.183 pct; V_2O_5, 0.30 pct; and $CaCO_3$, 9.7 pct. This ore is typical of the fabulous Mi Vida metallurgically, although certainly not representative in average grade. It contains most of the uranium and vanadium in chemically reduced form. A laboratory test shows an extraction by sulfuric acid leach of 91.5 pct, a reason-

Thirty-inch stainless steel CST ion exchange units with a volume of 95 gal each set up for uranium extraction from slurry.

able figure for low grade ore. No oxidant was used, despite the reduced form of the metals, nor did it appear necessary to use one, either in laboratory or pilot plant scale. The agitators used in the leaching section introduced considerable air into the pulp.

Owing to the excellent loading of U_3O_8 on standard mesh Amberlite IRA-400 resin, it was soon discovered that the 24 lb of available uranium oxide in the 8 tons of Mi Vida ore would be insufficient to test the system adequately. Accordingly, additional uranium was obtained to reinforce the uranium level of the leach pulps.

The pilot plant equipment to handle ore at the rate of 2 tpd (very conservative rating) includes primary and secondary crushing machinery, ore bin with belt feeder, ball mill with screw classifier in closed circuit with it, sand pump, four wooden leach tanks with rubber-covered flotation-type impellers, and a larger agitated tank for pulp batch makeup. Sand-slime separation was, of necessity, by batch decantation. This section of the plant was mounted outdoors.

Indoors, the pilot plant equipment consisted of six 30-in. stainless steel ion exchange units, with a total volume of 95 gal each. Four of these units were operated on exhaustion and two on elution. At the time this was believed to be somewhat inadequate, but since the whole idea was as yet incompletely proven, this was thought to be enough machinery either to prove or disprove the idea. It was.

Countercurrent resin flow between units was by airlift. This is one of the few methods of moving resin that result in low attrition of resin particles.

Simple provision was also made for collecting eluate and precipitating the uranium with MgO. Primary emphasis was placed on the resin-in-slurry ion exchange operation. The remainder of the plant was merely adjunct and some inefficiencies in leaching and sand slime separation were tolerated, since these sections produced a suitable pulp for ion exchange even under the circumstances.

Pilot operations on uranium extended over four months, during which some 12 separate runs were accomplished, some longer, some shorter. Soluble extraction of uranium was good; operating difficulties were minor. Techmanix succeeded in using standard particle size (20 to 50 mesh) Amberlite IRA-400 resin in the continuous countercurrent system. Since the action with this size was satisfactory, there is reason to believe that practically any standard resin can be used. This extends the possibilities to many metals and many resin types, cation as well as anion, and the method is not necessarily limited to metals.

Use of a continuous countercurrent ion exchange unit with integral slurry-resin separation is a fresh approach to the ancient problem of avoiding liquid-solid separations in hydrometallurgy. As applied to the processing of uranium, this particular process has advantages over other solutions:

1) Capital cost of the ion exchange plant is low.

2) There are no mechanical moving parts in exchange units and resin transfer system.

3) It is possible to use standard IRA-400 resin, which is *three times* as effective as the coarser XE-123 on the basis of loading and cost.

4) The system makes use of time-proven resin and metallurgy.

5) Continuous processing is possible.

6) The method is equally applicable to acid and alkaline leach systems. In most alkaline leach slurries, mild steel construction is possible.

7) The process enables use of tough resin, thus reducing attrition losses.

Data presented by Hollis and McArthur[1] reveal that the most efficient use of resin in a resin-in-pulp system requires:

1) Maximum number of stages within economic limits, but with each stage smaller.
2) High solution flow rates.
3) High solution-to-resin rates.

These requirements are easy to meet in the continuous countercurrent ion exchange unit. Most effective elution requires:

1) Large number of stages, within economic limits.
2) Low flow rate of eluant.
3) High *resin-to-solution* ratios.

These requirements also can be met by proper design of Infilco's continuous countercurrent resin-in-slurry ion exchange plant. The whole elution system might be one tenth the size of the exhaustion circuit, or less, because of the smaller flow rate.

In operation of the pilot plant on uranium, the system has been found noncritical in adjustment. It was a pleasure to produce uranium in this pilot plant.

Reference

[1] R. F. Hollis and C. K. McArthur: The Resin-in-Pulp Process for Recovery of Uranium. *AIME Trans.*, April 1957, Vol. 208, p. 442.

THE SEARCH FOR LOWER COSTS
— PROBING THE PROCESSES

Recovery of Uranium from Lignites

By Edward S. Porter

Henry G. Petrow

MAJOR occurrences of lignite with significant uranium concentrations have been reported in western parts of the Dakotas, especially in Harding County, S.D., and Billings and Slope counties, N.D. Samples containing as much as 2 pct U_3O_8 were received at the Winchester Laboratory, but those deposits reportedly of major significance have generally contained 2 to 4 lb of uranium per ton of lignite. Most of the uranium appears to be associated with the carbon in the lignite as a urano-organic complex, although in most instances analysis of inorganic material has shown uranium values. Molybdenum is similarly associated with the carbon, and its concentrations generally parallel the uranium. The noncarboniferous material is mainly composed of gypsum, jarosite, bentonite, sandstone, and miscellaneous carbonates and silicates. The heating value of these lignites has been determined as about 3500 Btu on a dry lignite basis.

The ash content of lignite has varied widely, the important samples containing 30 to 60 pct ash on a dry lignite basis. Because of the significant upgrading of uranium values obtained by ashing the lignite, and because recovery of uranium from raw lignite presented formidable processing problems, major emphasis at Winchester has been placed on devising methods to recover uranium from lignite calcines. Proper roasting removes the problem of organic fouling of solutions, reduces the size of the leaching plant for an equivalent uranium throughout, and generally provides equal or better acid leaching efficiency with less acid than can be obtained from the raw lignite.

Restrictions have been necessary in roasting lignite in order to produce a calcine amenable to uranium recovery by acid leaching. It was noted that roasting temperatures higher than 600°C inhibited the solubility of uranium in acid solution. Roasting in a laboratory electric muffle furnace at a nominal temperature of 450°C until all carbon was burned provided calcine amenable to acid leaching procedures. When equipment of pilot plant scale was used (3-ft diam multiple hearth or FluoSolids roasters), there was a heat dissipation problem in controlling the combustion temperature of the roasting operation. Restriction of air may be only partially successful as a means of controlling the temperature, since reduction of uranium, which is detrimental to acid leaching efficiency, may occur when the oxygen is too severely restricted. Moreover, it was found that almost complete removal of carbon is required for optimum leaching efficiency, and there must be enough oxygen to allow complete carbon combustion. Laboratory investigations have indicated that the carbon content of incompletely roasted lignite calcines can be controlled by flotation. Residual carbon can be floated out of the ash, either before or after acid leaching, and can be recycled to the roaster if practical operation of the roaster does not produce a carbon-free calcine. Flotation facilities are available at the Grand Junction pilot plant and can, if necessary, be incorporated into the lignite testing program.

Recovery of uranium from lignite ash by acid leaching required large quantities of sulfuric acid. For efficient recovery, the ash was contacted with

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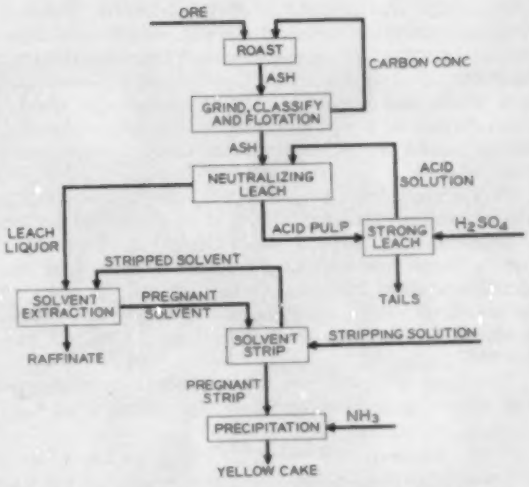
enough sulfuric acid in an aqueous slurry of water and ore to maintain a leaching pH of about 0.5. Adequate mixing of pulp generally required a pulp density of about 40 pct solids, as severe thickening of the mixture occurred when the acid contacted the ash. High leaching temperatures (70° to 90°C) were beneficial to efficient uranium dissolution, but a good deal of the heat requirement was supplied by the heat of reaction of the acid and the ash. The sulfuric acid requirement in a conventional leaching circuit would be 500 to 1000 lb per ton of ash (150 to 600 lb per ton of raw dry lignite). However, as optimum leaching extraction required considerable free acid at the end of leaching, two-stage countercurrent leaching procedures were used with effect. Up to about half of the co-current leaching acid requirement was saved by this procedure, which utilizes the excess acid to neutralize the acid-consuming minerals in the ash. Conventional leaching of lignite ash, with its high acid requirement, also resulted in a solution containing relatively high concentrations of undesirable metal ions and salts. The high molybdenum, ferric iron, and sulfate concentrations precluded direct ion exchange treatment of acid liquors. When countercurrent leaching was carried out at high temperature (over 90°C) these concentrations were reduced as much as 90 pct by precipitation, and the resulting solution was rendered amenable to ion exchange after contact with activated charcoal to remove residual traces of molybdenum. All acid liquors produced from ashed lignite were amenable to solvent extraction procedures.

Because of the high aqueous salt concentrations obtained by acid leaching of lignite ash, thickening and filtration were impractical unless flocculation aids were used. Flocculants produced satisfactory thickening rates when added as a dilute solution to the leach pulp. The amount of flocculant required was several times that for uranium ores treated on the Colorado Plateau, owing to the viscous nature of lignite ash acid pulps. In most cases filtration was practical only after a thickening stage. However, when the ash was properly handled, thickener and filter area requirements were lower.

Thickener underflows and filter cakes produced from solid-liquid separations of lignite acid pulps retained a large amount of solution. The lignite ash, after acid leaching, could only rarely be thickened to 50 pct solids, and in some cases terminal thickening densities of 30 to 35 pct solids were encountered. Filter cakes generally retained about 50 pct moisture. This tendency of the ash to retain moisture resulted in a high soluble loss of uranium from conventional washing circuits. A combination of thickening and at least two stages of filtration appears necessary to avoid excessive loss of dissolved uranium in acid leached residues.

Although other types of roasting equipment may be applicable to the processing of lignites, the Grand Junction pilot plant employs a FluoSolids reactor to produce a calcine. After grinding and classification, the calcine is subjected to a two-stage countercurrent acid leach, and the uranium-bearing acid solution is separated from the leached residue by thickening and filtration. The pregnant liquor is clarified and the uranium recovered by solvent extraction using an amine as the active agent.

Recovery of uranium by solvent extraction from sulfuric acid leach liquor by amines has been intensively studied.[1-6] There are commercially available, or potentially available, three long-chain amines that are excellent uranium extractants. These are triisooctylamine (TIOA), a tertiary amine manufactured by Carbide & Carbon Chemical Co.; Amine S-24, a secondary amine also available from Carbide & Carbon Chemical Co.; and Amine 9D-178, a secondary amine manufactured by Rohm & Haas.

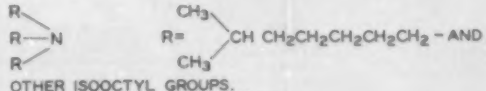


Lignite processing flowsheet of Grand Junction pilot plant. The need of a carbon flotation circuit will probably not be encountered.

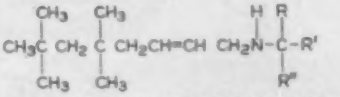
The mechanisms of uranium extraction and stripping when these amines are used are represented by the equation below. The forward reaction represents the extraction of uranium and the reverse reaction the re-extraction of uranium by chloride ion.

$$4R_3NHCl + UO_2SO_4 + 2SO_4^{=} \underset{\text{stripping}}{\overset{\text{extraction}}{\rightleftharpoons}} (R_3NH)_4UO_2(SO_4)_3 + 4Cl^-$$

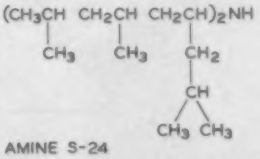
The principal advantage of the amines as uranium extractants is their selectivity for uranium. Of the ions commonly found in the lignite leach liquors, only molybdenum seriously interferes with uranium extraction. However, a very clean separation of uranium and molybdenum is easily achieved in the re-extraction or stripping operation. Chloride ion,

1. 

OTHER ISOOCTYL GROUPS.
TRI (ISOOCTYL) AMINE (TIOA)

2. 

WHERE R+R'+R" = 11-14 CARBON ATOMS
AMINE 9D-178

3. 

AMINE S-24

Structures of several uranium extractants.

which will quantitatively strip uranium from a pregnant uranium-bearing solvent, re-extracts only minor quantities of molybdenum. The molybdenum, however, is stripped from the solvent by an alkaline wash, and under nearly stoichiometric conditions. Either aqueous ammonia or sodium carbonate can be used to strip molybdenum from the uranium-free solvent.

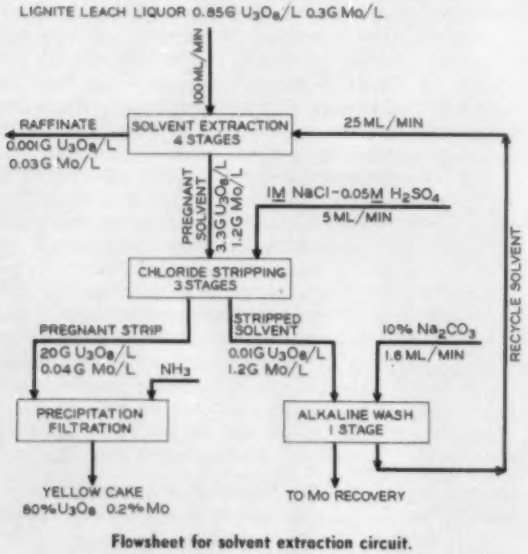
Ferric iron does not seriously interfere with the use of amine extractants. For this reason an amine is preferable to the organic phosphates for treating lignite leach liquors. This is especially true of the tertiary amines such as TIOA. Other ions such as ferrous iron, magnesium, calcium, aluminum, vanadium (IV), copper, and manganese are not extracted.

The table below shows the compositions of a typical leach liquor prepared by single-stage leaching:

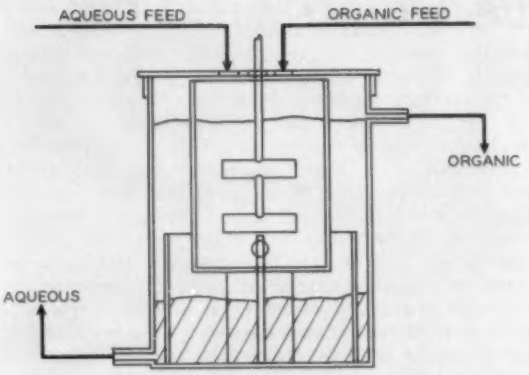
Constituent	Grams Per Liter
U_3O_8	0.85
Mo	0.30
Fe	8.8
Fe^{+++}	6.0
SO_4	130.0
AL_2O_3	20.0
pH 0.9	

As can be seen, the concentrations of ferric iron, sulfate, molybdenum, and aluminum are unusually high. This leach liquor, and others containing even higher concentrations of foreign ions, have been successfully treated by the procedure shown in the accompanying flowsheet for the solvent extraction circuit. In this case, a 5 volume pct solution of Amine S-24 in kerosene containing 2.5 volume pct of primary decyl alcohol was the solvent. The alcohol is added mainly to increase the rate of phase disengagement in both the extraction and stripping circuits.

The solvent extraction is performed in four mixer-settler stages, which generally have been found adequate to give efficient uranium recovery. With a leach liquor of the composition shown in the foregoing table, an organic-to-aqueous flow ratio of 1 to 4 is enough to give nearly quantitative uranium recovery and 90 to 95 pct molybdenum extraction.



Flowsheet for solvent extraction circuit.



The Winchester internal mixer-settler. This design is recommended for treatment of lignite solution, since it maintains a high organic-to-aqueous ration in the mixer-settler, eliminating the emulsion formation generally encountered with the conventional external mixer-settler design.

This results in a pregnant solvent assaying 3.4 g U_3O_8 per liter and 1.2 g Mo per liter.

The uranium can be re-extracted from the pregnant organic using 1*M* NaCl — 0.05*M* H_2SO_4 as the stripping solution. At an organic-to-stripping solution ratio of 6 to 1, three stages of conventional mixer-settlers are sufficient for 99.9 pct uranium stripping.

The uranium is easily recovered from the pregnant stripping solution, which will contain about 22 g U_3O_8 per liter, by precipitation with either ammonia or magnesium oxide. In either case, a final product assaying about 80 pct U_3O_8 and 0.2 pct Mo is obtained after drying.

The uranium-free solvent cannot be recycled to the extraction circuit without first removing the molybdenum. This is accomplished in a single stage by washing the solvent with a 1*M* sodium carbonate solution at an organic-to-aqueous ratio of 15 to 1. The solvent, nearly free of molybdenum, is then recycled to the extraction circuit. The molybdenum in the alkaline wash can be easily recovered by acidifying with sulfuric acid and precipitating molybdenum sulfide with hydrogen sulfide gas.

Until the pilot plant data are available, an economic appraisal of the process is premature, but it should be pointed out that the cost of roasting, which will probably be a significant part of the total recovery cost, is not encountered in treating ordinary uranium ores and that acid costs for leaching lignite ash can be expected to be two or more times the usual cost.

This work was performed under Contract AT (49-6)-924 AEC Raw Materials Div.

References

[1] K. B. Brown, C. F. Coleman, D. J. Crouse, J. O. Danis, and J. G. Moore: The Use of Amines as Extractants for Uranium from Acidic Sulfate Liquors—a Preliminary Report. *ORNL*, ORNL-1734, May 27, 1954.

[2] J. G. Moore, K. B. Brown, and C. F. Coleman: Further Studies of Amines as Extractants for Uranium from Acid Sulfate Solutions. *ORNL*, ORNL-1922, June 24, 1955.

[3] D. J. Crouse and K. B. Brown: Amine Extraction Processes for Uranium Recovery from Sulfate Liquors, Vol. I. *ORNL*, ORNL-1959, Sept. 30, 1955.

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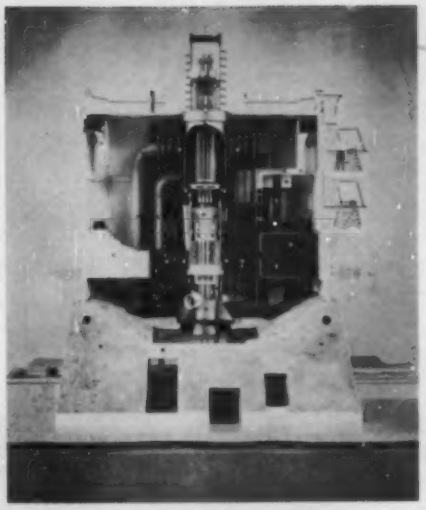
URANIUM UTILIZATION

MTR

Learning how to use uranium as fuel calls for test facilities such as the Materials Testing Reactor in Idaho, operated for AEC by Phillips Petroleum Co. At right the 9-ft high model of MTR displayed at Geneva Conference.

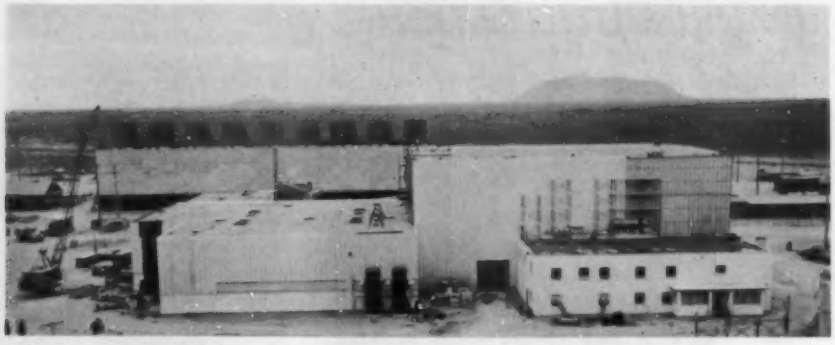


The Fuel Elements

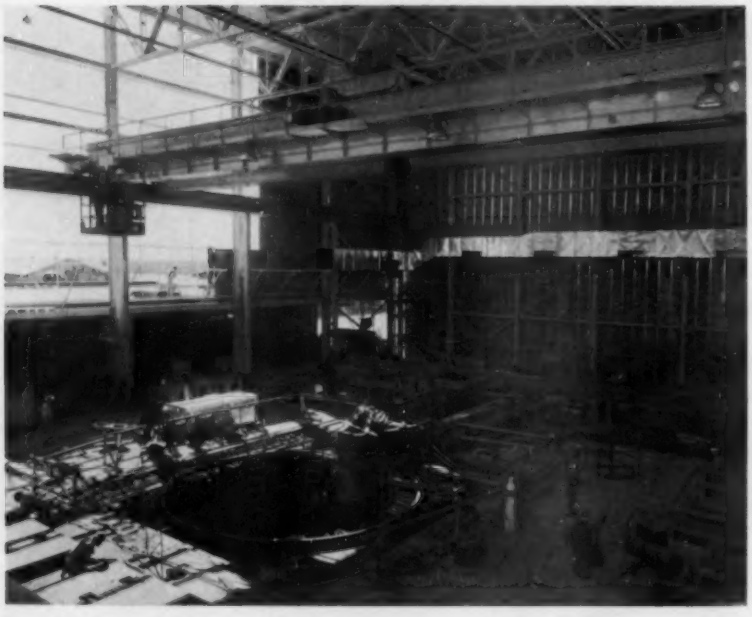
Plates within the fuel assemblies (3x3 in. by 2 ft overall), are made up of 0.02 in. thick alloy containing aluminum and U-235, and are aluminum clad. Cooling water flows between the plates inside the assembly. MTR uses 23 of these assemblies, plus four control rods.

The Reactor

MTR is a heterogeneous reactor using enriched uranium as fuel, and water (light) as both moderator and coolant. Currently operating at a heat output of 40 megawatts, it produces a thermal flux as high as 5×10^{14} neutrons per cm^2 per sec. The reactor core, surrounded by a beryllium reflector, is inside a 5-ft diam tank extending from 8 ft below the floor to 8 ft above, where it is closed by a top plug whose framework can be seen.



General view of the Engineering Test Reactor area at the National Reactor Testing Station in Idaho. Kaiser Engineers are executing construction for AEC.



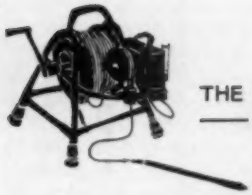
ETR

Because MTR does not meet all needs for experimental test facilities, an Engineering Test Reactor is nearing completion on an adjacent site. Designed to operate at a thermal power of 175,000 kw, ETR will provide neutron flux over a large enough volume of space for irradiation of larger engineering components than MTR permits. It will be operated for AEC by Phillips Petroleum Co. View above shows exterior. First floor of reactor building is at left.

and Fuel Recovery

ICPP

The major facility of the AEC for processing spent alloy-type enriched uranium fuel elements is the Idaho Chemical Processing Plant, also located at the National Reactor Testing Station in Idaho. This view of the operating corridor gives some idea of complexity of plant's control installation. The author points out that initial construction costs of such plants are high, as well as the operating costs, but that with sufficient volume the chemical processing of spent reactor fuel elements will be small compared to the cost of fabricating new elements utilizing the recovered fissionable material.



THE SEARCH FOR LOWER COSTS
—— PROBING THE PROCESSES

Past and Future Uranium Utilization

by R. L. Doan

WHEN the Plutonium Project was started in the spring of 1942 there was no technology to produce uranium metal of the required purity. Not only was there no such metal available; no one knew how to make it or fabricate it after it was made. Since this time vast technical effort has been expended in the atomic energy field. A short 15 years later the metallurgy of uranium is probably better known than that of any other metal, with the possible exception of steel.

At the beginning of the 1942 drive to obtain pure uranium metal the most available raw material was black uranium oxide (U_3O_8) of about 92 pct purity from the Great Bear Lake region of Canada. It took only three months for the project chemists to develop a process for bringing the purity of this oxide up to 99+ pct and another three months for Mallinckrodt Chemical Co. of St. Louis to build the purification plant and get it into operation. In early summer of 1942 the purified brown oxide (UO_3) started moving to the Metal Hydrides Co. in Beverly, Mass., and to the Westinghouse Research Laboratory in Bloomfield, N. J., both of which had been granted Government contracts to try to make pure uranium metal.

The Hydride method yielded a metal powder that was compressed into briquettes 1 in. square and ½

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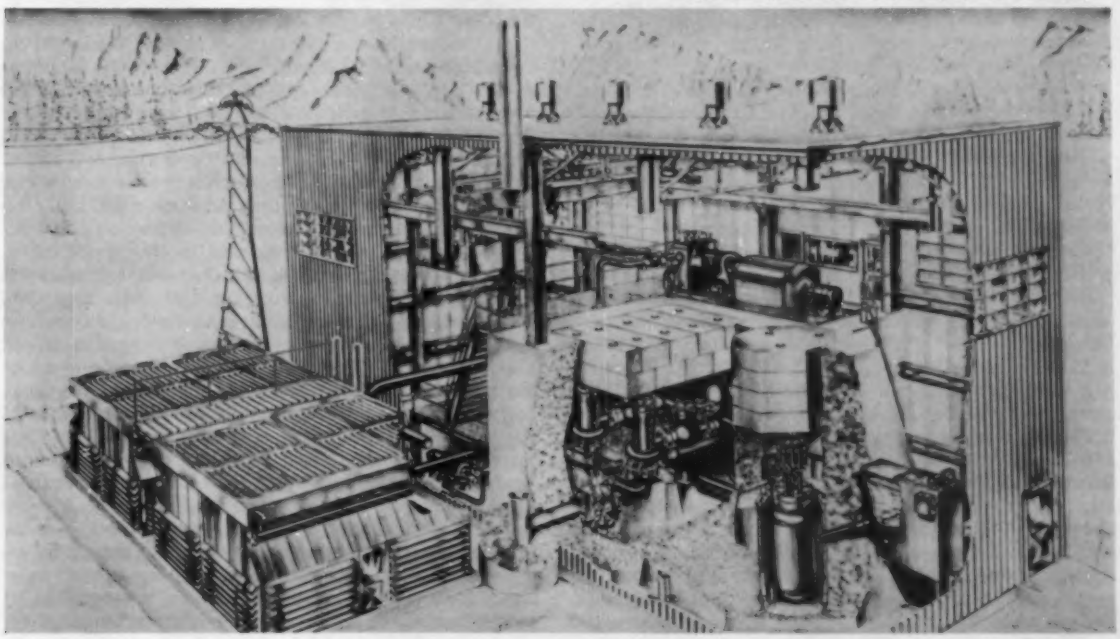
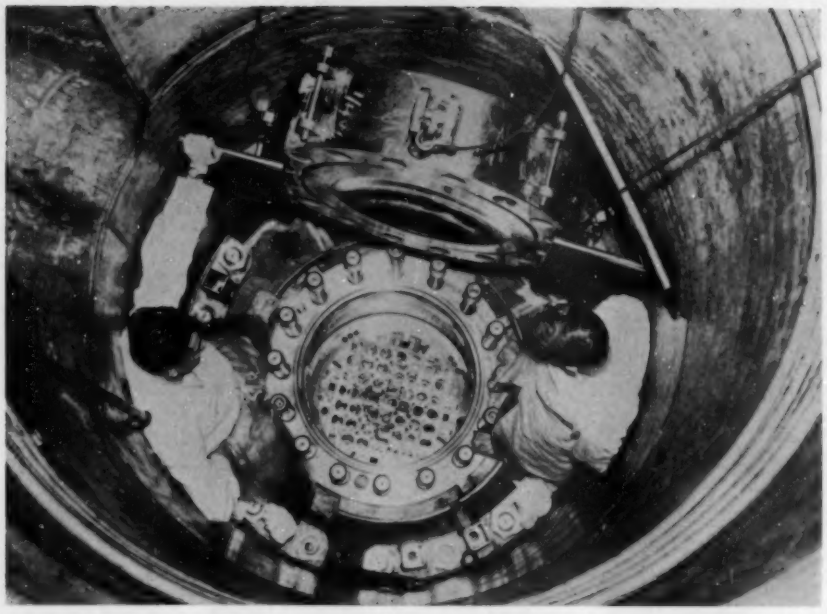
ORNL conceptual design of package power reactor.





Overhead view of core structure in Army Package Power Reactor as technicians make final installation. Note 7 x 7 grid with corners missing, providing space for fuel elements and control rods.

in. thick, but these were so highly pyrophoric that briquetting was later abandoned in favor of melting and casting. Westinghouse reduced the oxide by chemical and metallurgical methods, producing a metallic ingot that was sawed into 1-in. cubes. The late summer of 1942 saw a third entry in the metal production race when Iowa State College exhibited a perfect ingot of uranium metal obtained by reduction of UF_4 by calcium in a graphite-lined crucible. The world's first nuclear chain reaction, achieved at the University of Chicago Dec. 2, 1942, utilized uranium metal from all three of these sources, as well as a number of U_3O_8 briquettes placed around the outer portions of the graphite block structure, since there was not enough metal available to finish the job on the time schedule desired.

After the first chain reaction was achieved, the tempo of the Plutonium Project was accelerated. Design plans developed rapidly for the Hanford production units and also for a pilot plant at Oak Ridge where experience could be gained in production and chemical separation of plutonium for later application at Hanford when the major plants were completed. Du Pont Co. handled design and construction at both locations and also supplied large numbers of chemists and engineers for laboratory work. The University of Chicago assumed responsibility for operating the Clinton Laboratories at Oak Ridge with the object of isolating the first kilogram of plutonium. This activity formally got under way on Nov. 4, 1943, when the world's second nuclear reactor *went critical*. This natural uranium, graphite-moderated, air-cooled reactor was designed to operate at 1000 thermal kw but was boosted to 4000 kw shortly after being placed in operation. At its highest operating level it was capable of producing an ounce of plutonium every 8 to 10 days. The first activated uranium to be processed in the Clinton Laboratories semi-work processing plant was removed from this reactor (X-10) when the total plutonium content was about 1 g per ton. Since this amounts to a concentration of only 1 ppm, the 80 pct recovery achieved in this initial material was almost miraculous.

Such rapid strides were made during 1943 in solving the problems of uranium technology that when the Oak Ridge X-10 reactor went into operation less than a year after the first chain reaction at the University of Chicago, some 25 tons of uranium metal were used for the initial loading. Among the most formidable of these problems was the development of suitable casting techniques, hot fabrication methods, machining, and cladding. By mid-1943 hot-rolled uranium rods were being readily machined into smooth shiny rods and the official melting point had dropped from about 1800°C to below 1200°C. But cladding was still a big problem. Uranium metal oxidizes rapidly in the presence of air and water at elevated temperatures and must be protected when used as a reactor fuel. To achieve the necessary high heat transfer coefficients, the cladding must be metallurgically bonded to the uranium. The most suitable cladding material for the uranium cylinders used in both the Oak Ridge and Hanford graphite reactors appeared to be aluminum. Getting a good bond and closure required the major attention of several metallurgists over a considerable period of time. Failure of even one cylinder meant that oxidation would occur during reactor operation, with a consequent swelling and distortion of the slug, leading to the release of fission products, blocking of the coolant passage, and in the worst cases, local melting requiring a major reactor shutdown.

Uranium Supply During World War II: Even before the first chain reaction had been achieved in December 1942, it was clear that maintaining an adequate supply of uranium might become a problem. Mining operations in the Canadian Great Bear Lake region had to be curtailed or stopped during the worst winter months, and in no event was production great enough to meet anticipated demand. Early in the war, however, 1200 tons of 65 pct uranium oxide belonging to the Belgian Congo Mining interests had been transferred from a Belgian port to New York to prevent its falling into the hands of the Germans. This material had been stored in a New York warehouse for more than a year when it came to the attention of the Manhattan District

Corps of Engineers. An agreement was quickly negotiated with the Belgian representative in New York, and this supply provided the principal source of raw material for the plutonium and U^{235} projects during the war years.

Two major developments have accounted for most of the post-war activity in uranium exploration and production. One is the hydrogen bomb. The other is the growing supply of U^{235} beyond immediate military needs, sparking vast activity in the field of small mobile reactors for both military and civilian application. This supply has also given great impetus to the development of many different varieties of stationary nuclear power plants within the U. S. in an effort to find the best approach to nuclear power costs that will be competitive with those of plants utilizing conventional fuel. While natural uranium can be used in construction of nuclear power plants that are reasonably competitive with coal or oil in certain parts of the world (the United Kingdom has already taken this approach in its Calder Hall reactors), the availability in this country of sufficient quantities of U^{235} to permit *spiking* the natural uranium up to a higher enrichment makes for a much more flexible power reactor development program.

The first full-scale nuclear power plant in the U. S., now nearing completion at Shippingport, Pa., utilizes a pressurized light water reactor as the heat source. Coolant water leaving the reactor at high temperature and high pressure passes through a heat exchanger and generates steam in a secondary circuit used to drive the turbine generators. Design capacity is 60,000 net kw of electricity, but it is expected that output will go up to 100,000 kw. The most that can be said for this first plant is that it offered a quick approach to nuclear power based on design and operating information already well established. But the high investment cost of $1200 per installed kilowatt of capacity and the very high generating cost of 50 mils per kw-hr cannot be considered competitive with conventional power plants.

The AEC has recently announced that there are more than 200 nuclear reactors either in operation or in various stages of design and construction in this country. Most of these are low power reactors used chiefly for research, but many also are production or power reactors operating at high levels of heat generation. The total uranium requirement for the initial charges and fuel replenishment for all these reactors is substantial. Under President Eisenhower's Atoms for Peace program 40,000 kg of U^{235} have been committed to civilian reactor development at home and abroad, and much more will be required to sustain this program in future.

Taking into consideration the wide range of possibilities in the choice of nuclear fuel, moderators, coolants, neutron energy, fuel conversion, and breeding, hundreds of different nuclear reactors might be built if there were incentive for doing so. Not enough experience has been accumulated to determine what type of reactor might be most desirable to generate electric power in any given situation. From the several hundred different reactors theoretically possible, a dozen or so have been selected by various companies and institutions for construction in connection with power generation projects. Most of this is being done with partial or complete Government financial support, although a few plants are being financed entirely by private funds. The general method of power generation is the same for all these plants. Heat generated in the nuclear reactor core is carried away by a coolant fluid and given up in a heat exchanger where steam is formed which is used to drive the turbines.

At a site near Joliet, Ill., Commonwealth Edison Co. will build a 180,000-kw dual-cycle boiling water reactor plant; a 5000-kw experimental boiling water reactor plant is in operation at the Argonne National Laboratory near Chicago; a 100,000-kw fast breeder reactor plant of Atomic Power Development Associates is under construction at Lagoona Beach in the Detroit area; and the 5000-kw sodium-graphite reactor of Atomics International is ready for experimental tests near Los Angeles. Consolidated Edison will build a 140,000-kw pressurized water reactor at Indian Point, N. Y.; Yankee Atomic Electric Co. will build a 134,000-kw $35 million plant at Rowe, Mass.; and a 7500-kw organic moderated reactor plant is proposed for construction by the city of Piqua, Ohio. Construction of the 15,000-kw plutonium fast breeder (ERB-II) of Argonne National Laboratory will soon begin at the National Reactor Testing Station in Idaho; a 10,000-kw heavy-water modulated, sodium-cooled reactor plant is being designed by Nuclear Development Associates for the Chugach Electric Co. at Anchorage, Alaska; and the homogeneous thermal breeder project is under way at the Oak Ridge National Laboratory. The gas-cooled reactor that Aerojet-General will build at the National Reactor Testing Station is entering the development stage.

Economics of Nuclear Power: The economics of nuclear power will be determined by four major considerations: 1) cost of fuel fabrication; 2) fuel burnup attainable in the reactor; 3) conversion or breeding ratios; and 4) chemical reprocessing costs. All the major reactors built to date fall in the heterogeneous class, incorporating the nuclear fuel in a rigid metallic core structure distinct from the coolant and moderator. Considerable experimental work has been done, principally at the Oak Ridge National Laboratory, on homogeneous reactors in which the nuclear fuel is mixed uniformly with the moderator either in the form of a solution or a slurry, but no large-scale homogeneous reactors have been built.

Requirements for the core structure of heterogeneous power reactors are very severe. The fissionable material cannot at any time be allowed to come in contact with the coolant or moderators and must be protected by a cladding material that will stand up under the corrosive and erosive conditions encountered at high temperatures and high rates of coolant flow. Moreover, all core materials must have a low absorption for neutrons. This severely limits the field of permissible core metals and alloys. Aluminum is a satisfactory cladding material for operating temperatures up to about 400°F but will not withstand the corrosive effects of water at the higher temperature needed for power reactors. Only zirconium or its alloys and stainless steel appear to possess the desired characteristics for high-power operation, but core fabrication costs with either of these materials are very high, and both present special problems in dissolution which increase chemical reprocessing costs of spent fuel elements.

The burn-up attainable with a given core structure in a nuclear reactor is limited by fission product accumulation and by the length of time the fuel cladding can stand up under the operation conditions. Whenever a break occurs in the cladding so

that the highly radioactive fission products and some of the nuclear fuel leak out into the coolant stream, the reactor must be shut down for replacement of the defective fuel elements. Physical properties of the cladding material may be damaged by radiation, or the cladding may be broken by growth and distortion of the fuel itself, particularly if the temperature is allowed to rise above certain phase transition points.

Materials Testing Reactor: The only way to find out whether or not any particular type of core or core structure will stand up under the intense and prolonged neutron bombardment to which it will be exposed under operating conditions is to carry out exploratory investigations on small prototype samples in nuclear test reactors built especially for this purpose. The most outstanding facility of this kind is the materials testing reactor located at the National Reactor Testing Station in Idaho and operated by Phillips Petroleum Co. under contract with the AEC. The MTR is a water-moderated and water-cooled enriched uranium reactor operating at a thermal power level of 40,000 kw, providing the world's highest neutron flux at about $5x10^{14}$ neutrons per sq cm per sec.

Engineering Test Reactor: Because the MTR is not able to supply all of the demand for specialized experimental test facilities from AEC contractors and others, an engineering test reactor, nearing completion at a site adjacent to the MTR, is designed to operate at a thermal power of 175,000 kw, which will provide a maximum neutron flux in the range of 10^{15} over a large enough volume of space to permit irradiation of larger engineering components than can be accomodated in the MTR.

Reprocessing Spent Fuel: The value of residual unused fissionable material still in the core at the time it is taken out of the reactor is sufficient to justify the cost of its recovery. This means that the fuel elements must be disintegrated and put through a chemical processing operation in which the end product will be the recovered nuclear fuel. The cost of this operation arises almost entirely from the fact that the fission products in the spent fuel elements are extremely radioactive. Until they are separated out and disposed of in the course of the reprocessing cycle, all operations must be carried on behind heavy biological shields by remote control methods. Initial construction costs and operation and maintenance costs for such a plant are high, but if the plant is operated at design capacity, the cost of chemical processing of spent reactor fuel elements will be small compared to the cost of fabricating new fuel elements utilizing the recovered fissionable material.

Government Vs Private Control: The purchasing schedule established by the AEC assures a market at specified prices for all uranium produced up to April 1, 1962, and for limited quantities produced thereafter until Dec. 31, 1966. The Commission's buying power may or may not be extended further, but even if it is, this will put off for only a few years the time when the uranium industry must stand or fall largely on the basis of the economic value of nuclear fuel in competition with fossil fuels at any given location for the particular application under consideration.

It does not presently appear that there is any compelling economic incentive for developing nuclear power reactors with private capital. There are too many uncertainties as to operational reliability, handling and disposal of radioactive materials, investment, operation and maintenance costs, public liability, employe liability, dependability of fuel supply, and fuel fabrication and reprocessing costs. It is clear that most of the financing for the nation's nuclear power reactor program will have to come from government sources until these uncertainties have been resolved to a degree justifying private investment.

There is, of course, a hazard involved in allowing the government to take the sole initiative. In the absence of adequate controls, this could easily lead to a public power program in competition with private power that would dwarf anything that has been accomplished to date in the field of hydroelectric power. The higher cost of nuclear power, which must be taken into consideration by a private company, would probably be submerged in Federal accounting procedures and disappear in the general political clamor for development of a new fuel resource. To avert this trend, some of the larger utilities serving highly industrialized areas have reached the decision to build and operate several nuclear power plants.

The problem of public vs private power is just as pressing west of the Mississippi River, if not more so, but it is noteworthy that there have been no proposals for construction of a nuclear power plant from any of the private utilities in this area. The higher cost of nuclear power cannot readily be absorbed in the smaller investment structures of western companies without adversely affecting the power rates.

Is it possible to leave the financing and direction of the nuclear power reactor program entirely in the hands of the Government without jeopardizing the ultimate ownership and operation of nuclear power plants by private companies if nuclear power can compete economically with power from other sources? Yes, if steps are taken now to set up the legal framework. One requirement would be authorization and allotment of government funds for the AEC to contract with qualified industrial concerns for design, construction, and operation of all nuclear reactors capable of delivering substantial quantities of steam at pressures that would generate electric power. Another would be authorization for the Commission to build these reactors with Government funds at locations selected on the basis of high bids for purchase of the steam output by any private, municipal, or cooperative utility that could provide a site in the kind of environment specified for the particular reactor under consideration and would agree to build the generating part of the plant with its own funds. A third requirement would be legislation making it mandatory for the AEC, subject to congressional approval, to dispose of the reactor part of the plant to the highest bidder after the reactor has been in operation long enough to supply the technical, operational, and economic data needed to determine its overall feasbility for power generation purposes. Conceivably, this could occur within five years after initial operation of the reactor.

In the adoption of such a plan there would be many problems, both political and economic. Getting the necessary legislation framed and accepted by Congress would probably be more difficult than building and operating the nuclear reactors. But whatever plan is followed is certain to influence greatly the future growth of the domestic uranium industry.

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News of . . .
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Plan Now For Quebec In the Fall

Historic Quebec, its "old" city completely enwalled, will be the scene of the AIME-ASME-CIM Solid Fuels Conference, October 10 and 11. The gate shown is one of three through which a visitor must pass on his way to the Chateau Frontenac, headquarters for the Conference. For information on some of the men responsible for planning the meeting, turn to pages 1016 and 1018.

SME Divisions Name Officers To Serve in 1958

In the Society of Mining Engineers of AIME, the nominating committees of four Divisions—Coal, Industrial Minerals, Minerals Beneficiation, and Mining—have submitted the names of officers to serve in 1958.

Officers nominated to serve the Coal Division in 1958 are: Chairman (automatic), J. W. Woomer; chairman-elect, Raymond E. Salvati; executive committee (1958-1960), E. G. Fox, Clayton G. Ball, and E. Minor Pace; and secretary, D. R. Mitchell.

In IndMD the following have been nominated: Robert M. Grogan, chairman; John G. Broughton, secretary-treasurer; Donald R. Irving, Transactions Editorial Committee and

(Continued on page 1017)

Colorful Florida Offers Varied Entertainment For October Visitors Attending Conference

See page 1014 for the tentative technical program.

Sunny Florida in October with its many facilities for recreation and entertainment will be the site of the first annual meeting of the Society of Mining Engineers of AIME and the Southeastern States Mining Conference. The meeting, to be held October 15 through 18 at the Hillsboro and Tampa Terrace Hotels, Tampa, Fla., promises to set a precedent for meetings that will be hard to surpass in years to come.

Ladies' Program

The ladies of the Florida Section, host for the conference, have been hard at work planning a gala four-day program for the wives of visiting engineers, and have extended a cordial welcome to all who wish to make the trip with their husbands.

The Tides Hotel, modern, luxurious, and adjacent to the Gulf and snow-white beaches near St. Petersburg, will be the scene of the initial luncheon for the ladies. Visitors will be able to enjoy an excellent lunch and view the latest fashions to be paraded afterward.

Visit Cypress Gardens

No visit to Florida is complete without a trip to the famous Cypress Gardens, renowned for the water exhibitions held there. On Thursday, October 17, the ladies' committee has planned a luncheon expedition to the Gardens during which there will be a water show, including the famed ski acrobats, and a parade of colorful costumes by some of the state's lovely models.

On the concluding day of the conference, the ladies will go Spanish at the Siboney Room of the Columbia Restaurant in Tampa's Latin Quarter, known for its Spanish cuisine.

Mrs. Harvey Hardy, chairman of

(Continued on page 1022)

Typical scene at Cypress Gardens in Florida are these water skiers, part of the famed troupe of aquatic acrobats who will be viewed by the ladies on October 17 when they visit the Gardens for lunch. They will see the water acts and a bright parade of costumes.

Technical Program

First Annual Meeting Society of Mining Engineers Southeastern States Mining Conference

TUESDAY, OCTOBER 15, AM

Minerals Beneficiation

9:30—Gravity Concentration as Applied to Mesabi Range Intermediate Ores: *William R. Van Slyke and William H. Svigel,* Cleveland-Cliffs Iron Co.
10:00—Distribution Curves for Heavy Media Separation of Iron Ores: *R. G. Wuerker,* University of Illinois
10:30—Electrical Concentration of Iron Ores: *W. P. Dyrenforth,* Carpco Manufacturing Co.
11:00—Iron Ore Flotation on the Marquette Range: *E. W. Lindroos,* The Cleveland-Cliffs Iron Co.

Mining

9:30—Selection of Haulage Systems for Open Pit Copper Mining: *Adolph Sodenberg,* Consulting Engineer, Kennecott
10:00—Multiple Seam Coal Stripping and Belt Haulage: *S. F. Sherwood,* Stonefort Corp.
10:30—Dragline—Conveyor Stripping of Overburden: *L. M. Bredvold,* The M. A. Hanna Co.
11:00—Wheel Excavator: *Gene Long,* Truax-Traer Coal Co.

Geology and Geophysics

9:30—Phosphate Deposits of the Eastern United States: *J. B. Cathcart,* USGS
10:00—Petroleum Development in the Southeastern United States: *Ed J. Hamner,* Humble Oil & Refining Co.
10:30—Some X-Ray Diffraction Studies of the Leached Zone Minerals: *Robert W. Gould,* American Cyanamid Co.
11:00—Industrial Minerals in the Southeastern States: *Thomas L. Kesler,* Foote Mineral Co.

TUESDAY, OCTOBER 15, PM

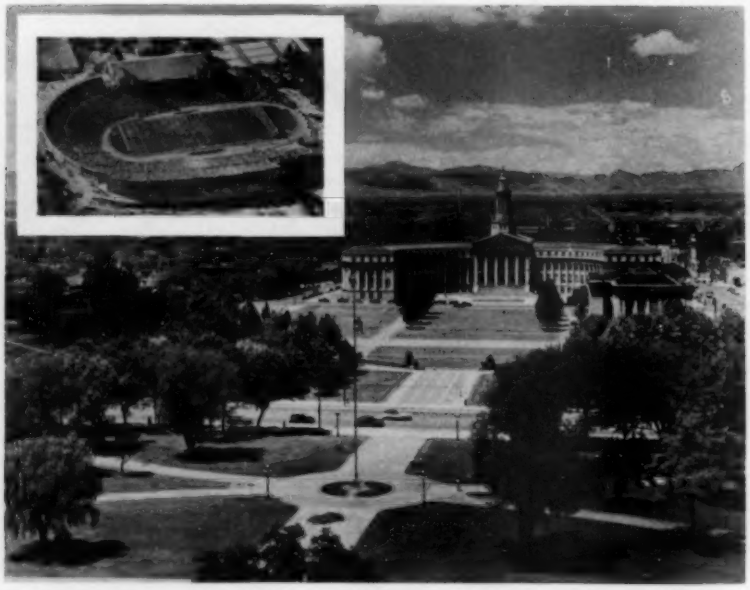
Minerals Beneficiation

2:00—Application of the Fluidized Solids Process to Drying: *William Brandt,* Dorr-Oliver Inc.
2:30—Heat Exchangers in Connection with Rotary Kilns: *R. W. Reedy, Maurice Shafer, E. N. Kunkle, and G. Niemitz,* Kennedy-Van Saun Manufacturing & Engineering Corp.
3:00—Sintering of Nickel Oxide at Nicaro, Cuba: *J. A. Poll,* Nickel Processing Corp.
3:30—Industrial Dust Collection: *G. G. Schneider,* Western Precipitation Co.

Mining

2:00—Application of Liquid Rheostats in Semi-Portable Mining Installation: *Richard W. Fugill,* Allis-Chalmers Manufacturing Co.
2:30—Modern Design of Electrical Cables for Mining Operations: *H. R. Stoddard,* Simplex Wire & Cable Co.
3:00—Maintenance of Electrical Cables for Surface Mining: *Steve Bunish,* Anaconda Wire & Cable Co.

Rocky Mountain Minerals Conference, October 30 to November 1



Denver, the "Mile High City," is to be the scene of the fourth annual Rocky Mountain Minerals Conference, Oct. 30 to Nov. 1, 1957. This panoramic shot was taken from the steps of the State Capitol, a mile high. In the background can be seen the snow-capped Rockies, a natural setting lending surrounding scenic beauty to the city. Shown in the inset is the Colorado University Stadium, Boulder, in which is to be held the University's homecoming game with Missouri. This event, scheduled for Saturday, November 2, promises to be the *field trip* highlight of the meeting. Technical sessions have been planned for Wednesday, Thursday, and Friday, and panels on uranium will be featured.

3:30—Inspection and Maintenance of Wire Rope to Extend Rope Life: *A. J. King and B. N. Carlson*, U. S. Steel Corp.

Mineral Economics

2:00—Economic, Technical and Legislative Changes in Mine Valuation Factors: *Samuel H. Dolbear and Frank H. Madison*, Behre Dolbear & Co.
2:30—Justification for Percentage Depletion: *C. E. Gable*, International Minerals & Chemical Corp.
3:00—Economic Evaluation of an Industrial Mineral Project: *J. E. Castle*, International Minerals & Chemical Corp.
3:30—Income Tax Deductions for Development and Exploration: *H. B. Fernald*, Loomis, Suffern & Fernald

WEDNESDAY, OCTOBER 16, AM

Minerals Beneficiation

9:30—Theory of Screening and Screen Selection Fundamentals: *H. J. Ritmeester, Jr.*, Hewitt-Robins Inc.
10:00—The Newer Classification Tools: *H. A. Bauer and H. W. Hitzrot*, Dorr-Oliver Inc.
10:30—Three-Inch Cyclone Improves Slime Recovery: *Robert Kingman*, National Lead Co.
11:00—Circular Concentrators for Gravity and Flotation Beneficiation: *Felix J. Losson, Jr.*, Cannon Concentrator Co.

Mining—Geology and Geophysics

9:30—Application of Photogeology to Mining Exploration: *K. N. Isaacs*, Aero Service Corp.
10:00—Problems Associated with Mining in the Kentucky-Illinois Fluorspar District: *Chester W. Shaw*, Aluminum Co. of America
10:30—Operations at the Canadian Johns-Manville Asbestos Mine: *J. O. Eby*, Canadian Johns-Manville Co. Ltd.
11:00—Mining Iron Ore at the Tennessee Coal & Iron Division, U. S. Steel Corp.: *Edward H. Stevens*, Tennessee Coal & Iron Div., U. S. Steel Corp.

Minerals Beneficiation—Industrial Minerals

9:30—Techniques of Cake Removal for Continuous Vacuum Filters: *W. M. Phillips and F. T. Weems*, The Eimco Corp.
10:00—Filtration Requirements for Uranium Concentrates: *D. A. Dahlstrom*, The Eimco Corp.
10:30—The Development of a Radioactive-Tracer Technique for Study of Grinding-Ball Wear: *M. Pobereskin, G. D. Calkins, A. Wesner, J. E. Campbell*, Battelle Memorial Institute, and *N. M. Ewbank*, Atomics International
11:00—Grinding Ball Size Selection: *Fred C. Bond*, Allis-Chalmers Manufacturing Co.

WEDNESDAY, OCTOBER 16, PM

Minerals Beneficiation

2:00—Fluorspar Beneficiation at the Alcoa Mining Division Plant at Rosiclare, Ill.: *W. C. Lay and G. M. Bell*, Aluminum Co. of America
2:30—Scale-Up Relationships in Spodumene Flotation: *William E. Horst*, Foote Mineral Co.
3:00—The Activation and De-Activation of Sphalerite with Silver and Cyanide Ions: *A. M. Gaudin*, Massachusetts Institute of Technology
3:30—The Effect of Chemical Reagents on the Motion of Single Air Bubbles in Water: *D. W. Fuerstenau and C. H. Wayman*, Electro Metallurgical Co.

Mining

2:00—Wobbler Feeder: *T. A. Oberhellman*, Hammermills Inc.
2:30—Sand Ilmenites of the Eastern United States: *Harry B. Cannon*, H. B. Cannon Assoc.
3:00—Some Recent Developments in the Use of Ammonium Nitrate as an Explosive: *D. F. Tikker*, Monsanto Chemical Co.
3:30—Brief History and Safety Comparison of Merex-Liquid Oxygen Explosives: *H. E. Keel and D. W. Mogg*, Great Lakes Carbon Corp.
4:00—Utilization and Economics of Merex-Liquid Oxygen Explosives: *H. E. Keel*, Great Lakes Carbon Corp.

Industrial Minerals

2:00—Recovery of Flakes Mica from Davy Crockett Lake by Dredging and Processing in a Unique Screening and Flotation Plant: *Ross LeGrand*, International Minerals & Chemical Corp.
2:30—Pelletizing Phosphate Rock: *R. E. Snow*, International Minerals & Chemical Corp.
3:00—Roofing Granules: *J. P. Sauls*, International Minerals & Chemical Corp.
3:30—Use of Perlite as a Filter Aid: *R. N. Hill*, International Minerals & Chemical Corp.

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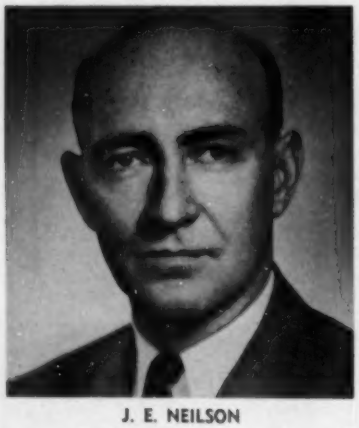
Many Help Plan for Joint AIME-ASME-CIM Solid Fuels Meeting

A. O. DUFRESNE

A. O. Dufresne, *Conference Co-Chairman,* is presently Deputy Minister of Mines for the Province of Quebec. He graduated from the Ecole Polytechnique as a civil and mining engineer, and received an M.S. degree at McGill University. He entered the Quebec Bureau of Mines at a comparatively early stage in the development of the metal mining fields of Western Quebec. Under his leadership, the QBM has grown considerably and it now includes some 70 engineers, geologists, and chemists. Mr. Dufresne is a past-president of CIM and of the Corp. of Professional Engineers of the Province of Quebec. He is also a member of the Engineering Institute of Canada and AIME. He is the recipient of honorary degrees from the Universities of Montreal and McGill.



J. E. NEILSON

Joseph E. Neilson, *Finance Committee,* is executive vice president of Foster Wheeler Ltd., St. Catherines, Ont. He graduated from Queen's University with a degree in mechanical engineering in 1928. Mr. Neilson has recently been elected to the board of directors of Foster Wheeler. He is a member of ASME, Engineering Inst. of Canada, and the Professional Engineers of Ontario.

Alexander Ignatieff, *Coordinating Committee* and a technical session chairman, was chairman of CIM's Coal Div. when a meeting was held in New York in 1954 with the ASME-AIME coal groups. This meeting was so succesful that Dr. Ignatieff suggested to CIM that another joint meeting be planned. As a result, CIM, through Dr. Ignatieff, issued the invitation to the groups for this 1957 Quebec meeting. Dr. Ignatieff, a native of Russia, is chief of the Fuels Div., Mines Branch, Dept. of Mines and Technical Surveys, Ottawa. He grew up in England where he graduated from the Royal School of Mines in 1927 with a degree in mining engineering. Prior to coming to Canada he had worked on numerous mining projects in Europe, Africa, and Central America. Dr. Ignatieff joined the British firm of Cardox in 1931 and four years later became chief engineer to direct technical and administrative operations. During this period he intensified his studies on coal, work that led to his appointment as special consultant on coal by the Canadian department. In addition to membership in AIME and CIM, Dr. Ignatieff is a Canadian councilor of the Institution of Mining Engineers of Britain and a fellow of the Canadian Geographical Soc. He is past-chairman of the Ottawa Branch, CIM.

A. IGNATIEFF

Gerard Letendre, *Finance Committee,* is senior partner of the Letendre, Monti and Assoc., consulting engineers. He has received the following degrees: B.A., University of Montreal; bachelor of engineering, McGill University; diploma in metallurgy, Imperial College of Science & Technology; Ph.D., Faculty of Engineering, University of London; and a diploma in economics, University of London. He has been professor of metallurgy and director of the Dept. of Mining and Metallurgy at Laval University since 1939. He is also a director, Quebec Board of Trade. Mr.

G. LETENDRE

Letendre is a member of CIM, ASM, AIME, the Iron and Steel Inst., the Inst. of Metals, and the Societe Francaise de Metallurgie.

Ian MacLaren, *Finance Committee,* is president of the Rochester and Pittsburgh Coal Co. (Canada) Ltd., staff of which he joined in 1927. He is also a member of the Dominion Coal Board. Dr. MacLaren was born in Saint John, N. B., and received his education at St. Andrews College, Toronto, and the University of New Brunswick, graduating with a B.S. in 1920 and an M.S. in 1922. Winner of the Military Cross for gallantry in the field, Dr. MacLaren served with the Royal Canadian Artillery during World War I. After the war and completion of his education, his first professional post was that of chief chemist at Cana-

I. MacLAREN

dian Explosives Co. Ltd. During World War II he served as Associate Coal Controller at the request of the Canadian government. Dr. MacLaren's service to his university, province, and the Dominion were recognized by the University of New Brunswick in 1950 when he was awarded the degree of doctor of philosophy.

(Continued on page 1018)

ROCK IN THE BOX

News of M.G.G. Division

We are continuing with our effort to acquaint AIME members with the organization and function of the MGG Division. If you are interested in mining, geology, or geophysics, you are either a MGG member or you are a potential candidate for membership. Incidentally, we charge no fees. You participate in Division activities through your regular affiliation with AIME and by letting AIME know that you want to be with us. We suggest you check your listing in the AIME Directory. If your interests are in MGG there should be a capital letter *A*, *I*, or *L* following your name, indicating that your major technical interest is in mining, geology, or geophysics. The geochemists are also being invited to join our Division as proposed in the new Bylaws that will be ready soon for your consideration.

The MGG Division operates on more of a national level as contrasted to activities of the AIME Sections that serve local areas.

In the past issues of MINING ENGINEERING we have presented the Divisional officers and provided information on activities of the Program Committee responsible for those excellent papers prepared for the AIME Annual Meetings held each February. Another function of the Division is review of papers for publication in MINING ENGINEERING as handled by the three Divisional Publications Committees. Their activities were explained in this column last month. Our Division Membership Committee will be introduced in a future issue of *Rock in the Box*.

This month we want to acquaint you with the MGG Division's Executive Committee. This is really the Division Board of Directors whose function is to advise our officers on planning and policy. The Bylaws provide that the Executive Committee will consist of the MGG chairman; the three vice chairmen for Mining, Geology, and Geophysics; the nine chairmen of the respective Program, Publications, and Membership Committees; and the most recently available past-chairman and vice chairman of the Division. This appropriately ties the current officers and committee chairmen together with former officers having experience in Division affairs.

Following is the representation on the Executive Committee in the various Subdivisions:

Mining
H. C. Weed
Elmer A. Jones
Roger E. Pierce
R. D. Satterley
John G. Hall
John M. Ehrhorn

Geology
Edward H. Wisser
Donald M. Fraser
Paul C. Henshaw
T. N. Walthier
H. R. Gault

Geophysics
Ralph Holmer
H. V. W. Donohoo
Walter E. Heinrichs, Jr.
Herbert E. Hawkes, Jr.
Harold M. Mooney

Clark L. Wilson is chairman of the Division and also acts as chairman of the Executive Committee. Not only do we have a good cross section of our field of interest, but you will note a well balanced geographical spread in our committee membership.

We hope you are interested in what the committee does and how it acts. Of course, we urge the committee members to attend the AIME Annual Meeting and participate in the MGG business session. Plans are now being made for the meeting in New York in February 1958. On Wednesday of that meeting we plan an all-MGG Division day, as far as our program is concerned, with presentation of Jackling and Peele Awards at a noon luncheon; and following the Jackling lecture, we will have an all-MGG business meeting. This is the big session for the Executive Committee and interested membership. During the year our business is conducted by mail. Problems considered so far include publication of Subdivision directories (the majority opinion vetoes this idea), formulation of a different preprint policy for Annual Meeting papers (we hope to have a constructive plan soon on this matter), and adoption of revised Bylaws for MGGD that will change our name to eliminate subdivisions and work toward coordination of effort by those engaged in mining and exploration. This revision has taken considerable time but we feel it is constructive work and we are planning for the adoption of the new rules prior to the Annual Meeting next February.

Clark L. Wilson

SME Divisions Nominate Officers

(Continued from page 1013)

R. C. Stephenson, General Editorial Committee. The regional vice chairmen are: T. E. Gillingham, northeast; Charles E. Hunter, southeast; John B. Patton, mid-continent; Henry G. Fisk, Rocky Mountain; Howard A. Ziebell, Pacific northwest; Lauren A. Wright, Pacific southwest; and Alex B. Jackson, Canadian. The following will serve on the Executive Committee: A. O. Bartell, 1957-1958; Pauline Moyd, alternate; Frank R. Hunter, David M. Larrabee, and G. Donald Emigh, 1958-1961. A. B. Cummins and R. M. Foose have been chosen to serve on the Mining Society Nominating Committee as members, with G. H. Chambers and R. C. Stephenson as alternates.

The MBD nominating committee has submitted the following: S. D. Michaelson, Society Director (since chosen as President-Elect for 1957); Nathaniel Arbiter, division chairman; Wayne L. Dowdey, associate chairman; H. R. Spedden, 1st regional vice chairman; Neil Plummer, 2nd regional vice chairman; Walter J. Snavely, secretary; F. T. Davis, Symposium Committee; D. A. Dahlstrom, Solids-Fluids Separation Committee; L. J. Erck, Pyrolysis & Agglomeration Committee; C. M. Marquardt, Operating Control Committee; Henry W. Erickson, Membership Committee; E. C. Herkenhoff, Crushing and Grinding Committee; R. H. Lowe, Concentration Committee; P. L. de Bruyn, Education Committee; Harry L. McNeill, Mill Design Committee; James H. Robins, Materials Handling Committee; and B. H. McLeod, Solution and Precipitation Committee.

Nominated for the MGGD Division were: H. Carroll Weed, chairman; John G. Hall, chairman for mining; Lyman H. Hart, chairman for geology; and Robert J. Lacy, chairman for geophysics.

Solid Fuels

(Continued from page 1016)

Eugene Larochelle, member of the *Quebec Committee* and the *Coordinating Committee,* is secretary-general of the Quebec Metal Mining Assn. He is a member of CIM.

E. LAROCHELLE

Earl R. Mitchell, *Conference Coordinator,* is presently head of the Mechanical Engineering and Combustion Section of the Fuel Research Laboratories, Mines Branch, Dept. of Mines and Technical Surveys, Ottawa. He received a B.Sc. degree in mechanical engineering from Queen's University. He is a member of ASME, the Inst. of Power Engineers, and the Assn. of Professional Engineers of Ontario. He had been associated with the Canadian Westinghouse Co., the Bailey Meter Co., and the Canadian International Paper Co., before joining the Dept. of Mines & Technical Surveys.

The Technical Program appeared in the August issue, page 908.

E. R. MITCHELL

Theodore S. Spicer, *General Conference Chairman,* is professor of fuels technology at Pennsylvania State University, Mineral Industries Experiment Station. He received his education at the then Pennsylvania State College and was at one time associated with the coal preparation and dryer division of the Link-Belt Co., Chicago. Many of his technical articles have been published by AIME.

T. S. SPICER

H. B. Charmbury, *Conference Co-Chairman,* reports that the program committee has been busy preparing the schedule of technical sessions. (For the Solid Fuels Conference technical program, see page 908, MINING ENGINEERING, August issue). Mr. Charmbury is professor of mineral preparation, School of Mineral Industries, Pennsylvania State University, University Park, Pa.

C. L. O'BRIAN

C. L. O'Brian, *Chairman of the Finance Committee,* is presently associated with the Dominion Coal Board as assistant to the chairman. He received a B.Sc. in chemistry from Queens University. He had worked for 12 years in industry and government service as a chemical engineer. In 1935, he was appointed to the Dominion Fuel Board, and in 1940, assistant to the Coal Administrator. Mr. O'Brian is the author of many technical papers.

C. E. Baltzer has been acting as *Publicity Chairman* for the Conference. Mr. Baltzer is with the Fuels Div., Mines Bureau, Ottawa. **William Bradbury** has been assisting with public relations details.

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SME Plans For AIME Annual Meeting Progress Rapidly

Preparations and plans are well under way for the Society of Mining Engineers' part in the AIME Annual Meeting to be held in New York, Feb. 16 to 20, 1958, with headquarters at the Hotels Statler and Sheraton-McAlpin.

Those attending the meeting will participate in stimulating technical sessions, including the all-Institute session on Tuesday afternoon. Following the session, the AIME Annual Business Meeting will be held, at which time AIME President Grover J. Holt will present his report on the state of the Institute.

Social Events

The social events planned include the Society of Mining Engineers' annual banquet on Tuesday. All-Institute events will include the dinner-smoker on Monday, the informal dance following the Society dinners, and the AIME banquet on Wednesday at which Augustus B. Kinzel will be installed as 1958 AIME President.

Delegates to the Annual Meeting will also have an opportunity for first-hand inspection of the site of the new Engineering Center which will be completed in the next few years. Located near the United Nations buildings on First Ave., the new site is reported on in detail on page 969.

Society Activities

Gill Montgomery, who is acting as program coordinator for SME, reports that all Divisional committees are operating in high gear.

The Society of Mining Engineers will join The Metallurgical Society and the Society of Petroleum Engineers of AIME in sessions under the jurisdiction of the AIME Councils of Education and Economics. As has been customary at past meetings, the Education sessions will be held on Sunday.

Coal Division

George L. Judy, Coal Division program chairman, reports that the Division is planning seven sessions. Two will deal with coal preparation. Another will be devoted to a symposium on bumps in coal mines. The remaining sessions will be taken up by technical discussions of coal mine ventilation, mechanization, and safety.

Industrial Minerals

IndMD's committee, under the direction of T. E. Gillingham, Jr., reports that the Division will hold five sessions. Two of these will be joint sessions with MGGD and MBD. Probable subjects are titanium raw

(Continued on page 1022)

Note for Members of the Society of Mining Engineers

Make October Guest Month

Invite your associates to attend the October meeting of your Local Section.

Show him AIME in action.

Tell him of other AIME meetings he would be interested in attending. (Refer to page 1036 for coming events.)

Ask him to fill in an application blank.

Every mining man should be a member of SME of AIME.

Around the Sections

• **Yavapai Subsection,** Arizona Section, has been holding once a month cocktail hour-dinner meetings. In April, members of the Subsection heard Robert Searls give a talk on a recent trip to Iran, Turkey, and Ethiopia. The travelogue was illustrated with colored slides.

In May the speaker was Jack Q. Jones of Shattuck Denn Mining Corp. who spoke on uranium milling.

Mr. Arthur Still, who was the June meeting speaker, illustrated his lecture on his consulting trip to Panama and Peru with a colored film.

A discussion of mining in South Africa, amply illustrated with colored slides, was the subject of the July meeting. Guest speaker for the occasion was J. A. McAllister of American Cyanamid Co.

• The members and their families of the **St. Louis Section** had a wonderful time on a picnic at Pleasant Dell, Mo., on June 23. The afternoon was devoted to swimming, softball, and other athletic activities after lunch provided by those attending.

• Two successful plant and field trips were enjoyed by members of the **Adirondack Section** in June and July. Highlighting the June 23 event was the visit by AIME President Grover J. Holt who, with AIME Secretary Ernest Kirkendall, joined Section members in a tour of the St. Lawrence Seaway and New York State Power Authority Project. The tour, arranged by A. Mellett of Uhl, Hall & Rich, major contractors, was a three-part affair: a view of the entire project via a 20-ft model, bus trip around the works, and a lecture with colored slides giving the chronology of the project. Mr. Holt spoke to members attending the dinner held at the Town House Restaurant in Potsdam, 20 miles from the Massena, N. Y., headquarters of the Seaway Project.

The second of the Section's summer events was a trip on July 27 to the Canadian Johns-Manville installation at Asbestos, Que., where members toured the 10,000-tpd underground Jeffrey Mine, the open pit, and the mill which was opened in September 1954. While their husbands were visiting Asbestos, the wives enjoyed the facilities of nearby Sherbrooke. That evening the group enjoyed a filet mignon dinner and dancing at the Hotel Sherbrooke.

Winners of the Section's Student Essay Contest were: first, Edward Phoenix, Clifton-Pine Central School; second, Mary McAdam, Gouverneur; and third, Jean McIntosh, Gouverneur. Honorable mention prizes went to Joyce Lahey, Long Lake; Roger Dusharm, Edwards; and Darleen Carpenter, Mineville. The winning papers were selected from among 46 from six competing schools in the Adirondack Section area. George Erdman, Gouverneur Talc Co., is chairman of the contest committee.

• The **Colorado MBD Subsection** wound up a successful year on May 11 at the Broadmoor Hotel, Colorado Springs, with W. Ahlberg, retiring chairman, presiding. Wayne Hazen, G. F. Richards, James V. Thompson, and Howard Keil presented papers at this wind-up meeting.

New officers elected for next year are: John R. Purdy, chairman; James L. Lake, vice chairman; and F. T. Davis, secretary-treasurer. The new chairman has appointed the following committees: program, Henry Wardwell for the Glenwood Springs, Colo., meeting and James H. Keener, for the Colorado Mining Assn. breakfast, Denver, and the Colorado Springs meeting; technical papers, Jack Mellin for the Colorado Springs meeting and Henry Wardwell for the Glenwood Springs meeting; membership, Roy VanZante; and nominating, Douglas Newton. The Subsection will resume its activities in the fall at the Denver Hotel, Glenwood Springs, on September 28.

Energy is Our Business **is a new 16-mm sound color film of 38-min duration, available free except for shipping costs, from the Motion Picture Dept., Westinghouse Electric Corp., 3 Gateway Center, Pittsburgh 30, Pa. Noted actors, John Boles and Arthur Franz, dramatize the story of the fast growing electrical industry. Striking gains in comforts and conveniences enjoyed by the average American family are illustrated.**

This New World of Metals **is a 16-mm sound color film which runs 20 min, available free except for shipping expenses from the Motion Picture Dept., Westinghouse Electric Corp., 3 Gateway Center, Pittsburgh 30, Pa. America's very survival might well depend upon our developments in the field of metallurgy, where metals are being subjected to rigid conditions such as the tremendous stress and skin temperature of today's high flying jet planes. This interesting film is a guide through one of America's newest pilot production facilities for the research, development, and processing of new metals and alloys.**

Applications of R.F. Induction Heating **is a new 16-mm sound color film which runs 15 min, available free except for shipping charges from the Motion Picture Dept., Westinghouse Electric Corp., 3 Gateway Center, Pittsburgh 30, Pa. This factual film shows the advantages and the success of RF heating when this process is used to through-heat, harden, anneal, solder, or braze metals. In actual operations, you see the varied applications of RF heating for the manufacture of metal parts and assemblies. Case histories are presented showing advantages and economies for heat-treating of metals.**

The United States Steel Film Distribution Centers **have released a new series of films which are available free except for shipping charges. The film distribution centers are located as follows:** *Birmingham Film Distribution Center,* **Tennessee Coal and Iron Div., General Offices, Fairfield, Ala.;** *Chicago Film Distribution Center,* **USS Public Relations Dept., 208 So. La Salle St., Chicago 90, Ill.;** *Cleveland Film Distribution Center,* **American Steel and Wire Div., Rockefeller Building, Cleveland 13, Ohio;** *New York Film Distribution Center,* **USS Corp., 71 Broadway, New York 16, N. Y.;** *Pittsburgh Film Distribution Center,* **USS Advertising Div., 525 William Penn Place, Pittsburgh 30, Pa.; and** *San Francisco Film Distribution Center,* **Columbia-Geneva Steel Division, 120 Montgomery St., San Francisco 6, Calif. Information on use of films outside the U. S. should be secured from** *United States Steel Export Co.,* **30 Church St., New York 8, N. Y.**

A review of a few of the interesting films is given as follows: *An Orchid to Mr. Jordan* **is a 16-mm (or 35-mm) sound color film which runs 25 min. This film shows the production of USS Stainless Steel, the fabrication of this metal, and how it makes contributions to health and better living.** *Sinews of the South,* **another 16-mm sound color film with a projection time of 34 min, is the story of the largest fully integrated steel producing company in the South. The film includes scenes from the ore and coal mines, quarries, conditioning plants, blast furnaces, open hearth furnaces, and operations in the various rolling and finishing mills. This film is available only from the** *Birmingham Film Distribution Center,* **and distribution is limited to the following states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas;** *Walls Without Welds* **is also a 16-mm (or 35-mm)**

sound color film with a running time of 28 min. Here for the first time are shown technicolor pictures made in the largest and most modern mills in the world devoted to the manufacture of tubular goods. The film includes views of the manufacture of large diameter seamless pipe showing the operations of the High-Mill, rotary rolling, reeling, sizing, and finishing.

Westinghouse Sound Films, **a catalog of 16-mm sound films available free except for shipping charges, lists some 47 general interest, product information, and training motion pictures. Copies of the catalog, booklet B-7077, are available from Westinghouse Electric Corp., P.O. Box 2099, Pittsburgh 30, Pa.**

Engineering Center

(Continued from page 969)

Carey Garage Corp. containing a garage with entrance on E. 48th St., and a vacant lot at the corner of First Ave. and E. 47th St. of which Peter W. Kuhn is the owner.

Previously acquired from the 849 First Ave. Corp. was a parking lot facing the United Nations Plaza, and a five-story tenement building at 344 E. 48th St. owned by Wallace Carter of New York.

All negotiations were made through Cross and Brown Co., 270 Madison Ave., New York.

In addition to Mr. Barrett, president, officers of the United Engineering Trustees Inc. are: Willis F. Thompson of New Haven, Conn., and Andrew Fletcher of New York, vice presidents; Joseph L. Kopf of New York, treasurer; and S. W. Marras of New York, secretary.

MINING ENGINEERING will bring you reports of the details of planning, design, and financing as rapidly as they become available.

Mineral Industry Meetings

Sept. 12-14, Wyoming Geological Assn., 12th Annual Field Conference, Southwestern Wind River Basin, with headquarters in Lander, Wyo.

Oct. 3-5, Seventh Annual Exploration Drilling Symposium, University of Minnesota, Center for Continuation Study, Minneapolis.

Nov. 14-15, Third Annual Symposium on Mining Research, Missouri School of Mines and Metallurgy and USBM, Rolla, Mo.

Feb. 6-7, 1958, California Governor's Industrial Safety Conference, 8th annual statewide meeting including Mineral Extraction Section, Fairmont Hotel, San Francisco.

June 23-28, Third International Coal Preparation Congress, organized by the Centre d'Etudes et Recherches des Carbonnages de France, Brussels and Liege, Belgium.

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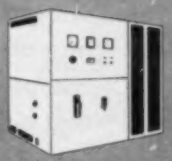

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Tampa Meeting

(Continued from page 1013)

ladies' events, reports that her fellow Floridians are looking forward to meeting all the ladies of the Society of Mining Engineers in October. They hope to make the event a memorable one for all attending.

Technical Program

H. E. Uhland reports that the program committee has an exciting list of technical sessions lined up, and that those mining engineers, industrial minerals and minerals beneficiation men, geologists, and geophysicists attending will find papers of excellent quality scheduled. The meeting committee plans to hold concurrent sessions on October 15, 16, and 17 for all groups. The fourth day, October 18, has been held free so that the conferees may participate in the deep sea fishing trip.

Detailed listings for all the technical sessions may be found on page 1014. This program, although still tentative, gives most of the final details. Any later changes in the conference program will appear in the October issue, MINING ENGINEERING.

Annual Meeting

(Continued from page 1019)

materials and nonmetallic mineral beneficiation, including a paper on cement grinding. There will also be a number of specialized sessions under auspices of Division commodity committees.

MGGD

MGGD, in addition to holding technical meetings of interest to each of its Subdivisions, is planning to devote a whole day to an all-MGGD session as at New Orleans.

R. H. Feierabend is coordinating Divisional activities. For the Mineral Subdivision, John G. Hall reports that his group will cover underground and open pit mining, safety, and operations in other countries as well as in the U. S. Herbert E. Hawkes, Geophysics, and his committee are planning sessions on explorations—techniques and case histories. The Geology group, under Thomas N. Walthier, will participate in the all-MGGD day and also hold technical sessions of special interest to the Subdivision.

Nominations for officers of the Society of Mining Engineers of AIME will appear in the October issue. These officers. if elected, will take office in February 1958.

Minerals Beneficiation

MBD and its program committee, steered by N. Arbiter, is planning joint sessions with IndMD as well as first-rate discussions on matters of interest to the whole Division.

Mining men all over the world are looking forward to the first New York meeting of the reorganized Institute. Plan now to be there.

Drilling Symposium Scheduled for October

The University of Minnesota School of Mines and Metallurgy, the Center for Continuation Study, and the Mining Subsection of the AIME Minnesota Section have once again planned the Annual Drilling Symposium. The 7th Annual Symposium will be held at the Center for Continuation Study on the University campus from October 3 through 5.

The first session, on the morning of October 3rd, will deal with the geophysical instrumentation of small bore holes. Drill hole electromagnetic exploration and radioactivity surveying of drill holes will be considered in detail. After a luncheon talk on the *Current Status of Diamond Drill Standardization*, by F. C. Sturges, Pennsylvania Drilling Co., the weighting and reliability of drill hole samples will be discussed. This discussion shall include a statistical approach to the problem.

The following morning, there will be a general session concerned with the role of diamonds in drill bits, surveying methods for small diameter bore holes, and the gyroscopic compass. A panel discussion on impregnated diamond drill bits will close the session. The afternoon session on air and mud as flushing media in exploration drilling, will include specific talks on core drilling under freezing conditions.

The discussion period on the last day will be followed by a luncheon and the Minnesota-Purdue football game. Information regarding football tickets, registration, and accommodations can be obtained from the Center for Continuation Study, University of Minnesota, Minneapolis 14, Minn.

Divisional Directory

The new Industrial Minerals Div. members directory is available to those who are not members of the division for $1.00 per copy. Send your dollar bill direct to

Industrial Minerals Directory
c/o AIME Business Office
29 W. 39th Street
New York 18, N. Y.

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PERSONALS

J. V. S. Norton has been promoted to assistant export sales manager, Bucyrus-Erie Co. and will work in the company's main office in South Milwaukee, Wis.

Philip D. Wilson has been elected a vice president of Callahan Zinc-Lead Co. He is a consulting mining engineer and geologist.

William W. Coleman was named honorary chairman of the board of Bucyrus-Erie Co., S. Milwaukee, Wis. His retirement as chairman of the board and of the executive committee comes after 52 years of association with the company. He was president for 32 years beginning in 1911. He is succeeded as board chairman by **William L. Little,** who continues as president.

W. L. Price, engineering manager of Keystone Div., and **D. H. Marlin,** research engineer, Dravo Corp., Pittsburgh, were winners in the company's 18th annual technical papers competition. They divided the $300 prize for their paper, *Abrasion-Resistant Materials Used in Sand and Gravel Production.* Honorable mention prizes of $50 each were awarded to **E. N. Hower,** manager of the Machinery Div., Industrial Dept.; and to **J. A. Anthes,** process engineer in the same department. Their paper discussed pelletizing and sintering fly ash.

James T. McMullan is now in North Bay, Ont., Canada, where he is working for Brunner & Lay (Canada) Ltd., Canadian branch of Brunner & Lay Inc.

L. H. Lange, vice president of The Galigher Co., Salt Lake City, returned home in June after a three-month trip to Africa and parts of Europe. During his stay in Africa, Mr. Lange worked on sulfide and oxide copper flotation for Union Miniere du Haut Katange in Kolwezi, Belgian Congo; helped the staff of Bancroft Mines, Northern Rhodesia, start their 4000-tpd flotation plant; and visited NChanga Copper Mines Ltd.; Mufulira; Chibuluma; Kilembe Mines Ltd., Uganda; and Sukulu Mines Ltd., Tororo, Eastern Uganda. Leaving British East Africa, Mr. Lange returned to Southern Rhodesia, where he completed consulting assignments for Dalny Mine and Rio Tinto. On his way home, he visited Zellidja Mine, French Morocco, and Titania A/S, Norway.

Richard F. Moe, formerly with the White Pine Copper Co., White Pine, Mich., as mine superintendent, is now manager of mines for the Kermoc Nuclear Fuels Corp., Grants, N. M.

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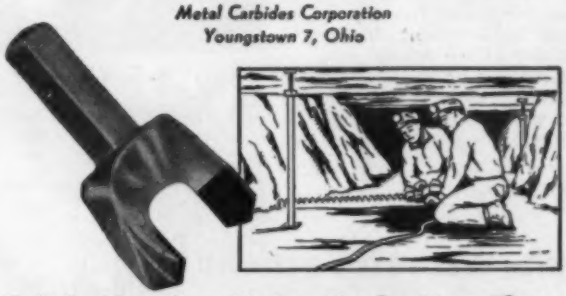

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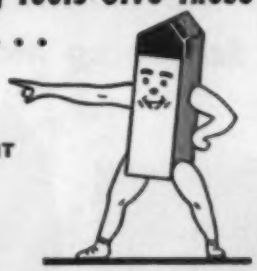

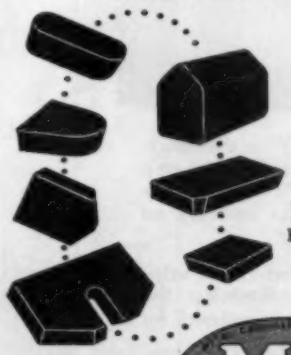

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R. M. FOOSE

Richard M. Foose has been appointed to head the newly formed Earth Sciences Dept. of Stanford Research Institute's Physical Sciences Div., Menlo Park, Calif. He was chairman of the Geology Dept., Franklin and Marshall College, Lancaster, Pa.

Howard G. Washburn, retired former general manager of Federal Mining and Smelting Co. was one of the six alumni honored recently for distinguished achievement in the mining industry at the annual commencement services of the Colorado School of Mines at Golden, Colo. The last position which he occupied prior to his retirement in 1947 was general manager of Federal Mining and Smelting at Wallace, Idaho. Other alumni awarded were: **A. S. Donnelly,** vice president, director, and manager of the Honolulu Oil Co., Midland, Texas; **John H. Wilson,** vice president of Piper Petroleum Co. and Woodson Oil Co., Fort Worth, Texas; **Charles D. Michaelson,** general manager, western mining division, Kennecott Copper Corp., Salt Lake City; and **Alfred R. Flinn,** eastern mines manager for New Jersey Zinc Co., Lake Mohawk, N. J.

H. G. WASHBURN

Rene Engel, consulting geologist and geochemist since 1935, recently moved his petrographic and geochemical laboratory from South Pasadena, Calif., to Wofford Heights, Kern County, Calif., where he is now residing.

Lyman C. Huff, formerly with the U. S. Geological Survey, Denver Federal Center, Denver, is now associated with the Military Geology Branch, USGS, Washington, D. C.

Donald C. Hardin, Jr., formerly with the Stamford, Conn., branch of Dorr-Oliver Inc., has been transferred to the Oakland, Calif., branch.

F. L. Knouse, assistant director, Div. of Rare and Miscellaneous Metals, Defense Minerals Exploration Administration, while on leave recently completed a consulting assignment investigating bauxite deposits in West Africa.

Walter F. Galloway, previously with Mac-Leod Cockshutt Gold Mines Ltd., Geraldton, Ont., Canada, is now associated with the AR Nickel Corp. Ltd., Worthington, Ont., as mill superintendent.

James D. Mulryan has been employed by the Sierra Talc and Clay Co., as mill superintendent and mining engineer, Long Pine, Calif.

F. R. Jones has been transferred from the Toronto branch of the

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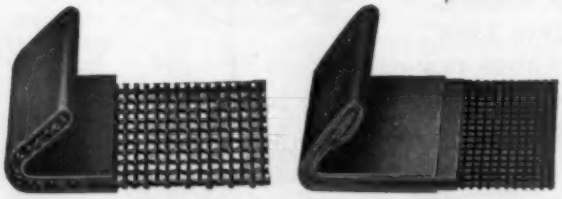

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Reno, Nevada	Telephone FAirview 9-0732
Denver, Colorado	Telephone WEst 4-0673
Alaska	Contact Salt Lake City Office

George M. Humphrey, former Secretary of the Treasury, has been elected chairman of the board of the National Steel Corp., Pittsburgh, succeeding the late Ernest T. Weir. Mr. Humphrey, an Honorary Member of AIME (1956), entered Government service in 1953. One of the founders of National Steel, he had long been associated with M. A. Hanna Co., Cleveland, leading producers of coal and iron ore. In 1929 when National Steel was incorporated, M. A. Hanna Co. stock holdings were involved in the merger. Mr. Humphrey, an organizer of Pittsburgh Consolidation Coal Co., was a director and chairman of the executive committee of National Steel in 1953 when he resigned to become Secretary of the Treasury. He has also been named director of M. A. Hanna.

Stanrock Uranium Mines Ltd., to the Elliot Lake, Ont., branch of the company, where he is mine manager.

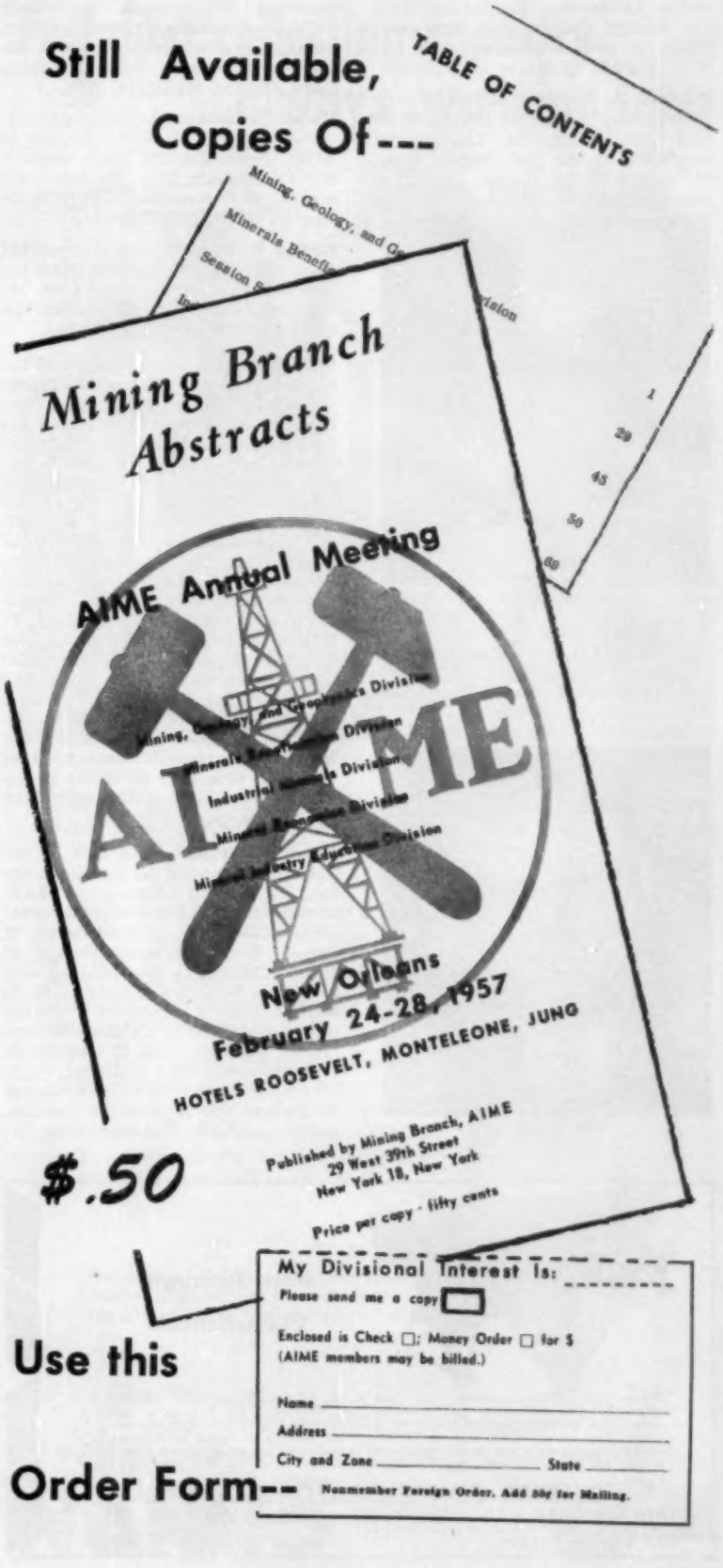
Robert Devlin is now associated with the Reynolds Mining Corp., Kwakwani, British Guiana.

James Edmunds, formerly chief engineer with the Potash Co. of America Ltd., at Saskatoon, Sask., Canada, is now employed as chief mining engineer with the Western-Knapp Engineering Co. in San Francisco.

Eugene C. Anderson, mining engineer, who was recently retired from the New Mexico Bureau of Mines and Mineral Resources, has opened a consulting office in Socorro, N. M.

John S. McNabb, Jr., recently was appointed head of the Engineering Dept. of Twin Star Industries Inc., Austin, Texas.

W. W. Little, mine superintendent, became general superintendent of the Copper Queen Branch of Phelps Dodge Corp., Bisbee, Ariz. **H. D. Clark,** also of the same company, has been named mine superintendent.



Roger L. Tenney, previously with the Braden Copper Co., Rancazua, Chile, is now associated with the U. S. Bureau of Mines in Duluth.

William A. Griffith, formerly with New Jersey Zinc Co., Bertha Mineral Div., Austinville, Va., is now employed by the Rare Metals Corp. of America, Tuba City, Ariz., as metallurgist.

R. L. SCOTT

R. L. Scott has been appointed manager of mining supply sales at The Colorado Fuel and Iron Corp. **Howard K. Schmuck, Jr.,** has been appointed assistant manager of mining supply sales for the same company.

H. K. SCHMUCK

Sherman R. Burdick, previously with the Fresnillo Co., Mexico City, Mexico, is now associated with the Round Mountain Gold Dredging Corp., Round Mountain, Nev.

Duane A. Houkom has been promoted to the post of sales manager of Atlas Copco Eastern Inc.'s Stationary Compressor Div. He had been serving as southeastern district manager in Knoxville, Tenn.

Lowell B. Moon has been appointed as development manager of the Kennecott Copper Corp., New York. He had been district geologist in the northwestern states and Alaska.

O. A. Rockwell, vice president of the Eagle-Picher Co. and general manager of the Mining & Smelting Div., has announced the following promotions and advancements in the company's Geology Dept.: **Joseph P. Lyden,** who held the job of chief geologist for the company for many years, will retire on Sept. 30, 1957, and **Douglas Brockie,** formerly senior geologist in the Tri-State District, has been promoted to chief geologist for the company's domestic operations and exploration; **Richard C. Lundin** will succeed Mr. Brockie as senior geologist in the Tri-State District; **Robert A. Chadwick, III,** who has been working on special projects in the Tri-State field, has taken over additional exploration work under Mr. Brockie; and **William E. Arnt** has been promoted to senior geologist in the Illinois-Wisconsin area operations and exploration.

David L. Francis, president of the Princess Elkhorn Coal Co., Huntington, W. Va., has been named chairman of the Natural Resources Committee, Chamber of Commerce of the U. S. Other appointments or reappointments in the minerals and industries fields are as follows: **H. Y. Bassett** (newly appointed), executive vice president, Calumet & Hecla Inc., Chicago; **John C. Carrington** (re-appointed), vice president, Freeport Sulphur Co., New York; **James T. Finlen** (re-appointed), western general counsel, The Anaconda Co., Butte, Mont.; **E. Phil Gemmer** (re-appointed), president, Texas Construction Material Co., Houston; **Frank E. McCaslin** (re-appointed), president, Oregon Portland Cement Co., Portland, Ore.; **Franklin G. Pardee** (re-appointed), president, Lake Superior Iron Ore Assn., Cleveland; **Walter L. Rice** (re-appointed), president, Reynolds Mining Corp., Richmond, Va.; and **Charles E. Schwab** (newly appointed), manegar, Employee and Public Relations Div., The Bunker Hill Co., Kellogg, Idaho. The Committee will meet this month in Salt Lake City.

F. A. Barrón has been promoted to general mine foreman, Quiruvilca Mine, Northern Peru Mining Co., Peru. He has been with the company since 1953.

A. B. WALTER

A. B. Walter, a pioneer of belt conveyerization in underground mines, is on a leave of absence from the Goodyear Tire & Rubber Co. that will extend into retirement this month.

Robert R. Beebe, formerly with the Dept. of Mineral Dressing, Montana School of Mines, is now with the Brunswick Mining and Smelting Corp. Ltd., Bathurst, N. B., Canada.

Jack H. How, chairman, led members of the San Francisco Chamber of Commerce Mining Committee on a two-day tour of northern California and Nevada mining areas in June. Among those making the trip were **Lewis M. Holland,** manager of the Chamber's industrial department; **Phil R. Bradley, Jr.,** chairman of the State Mining Board; **Worthen Bradley,** president, Bradley Mining Co., and vice president, American Mining Congress; and **George Vosper,** chairman, Chamber product potential subcommittee. The group visited the Leviathan Sulphur Mines, Alpine County, Calif., and The Anaconda Copper Co. mine, Weed Heights, Nev. During the tour, the committee met with the Mono County, Calif., Chamber of Commerce and the State Mining Board at Bridgeport, Calif.

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E. A. Hickok, round-water geologist, is now associated with the recently organized firm of Geraghty, Miller & Hickok, consulting ground-water geologists, in New York.

Dorr-Oliver Inc. announced that **Anthony Anable** has rejoined the staff of the company as manager of the Technical Div. with headquarters in the general offices at Stamford, Conn. Prior to his return, he was retained as a consultant to the company.

George A. Komadina has joined the staff of Pima Mining Co., Tucson, Ariz., as mill superintendent. Mr. Komadina formerly was chief metallurgist of the Mining & Smelting Div., Eagle-Picher Co., Miami, Okla.

Roy J. Grissom has retired as department manager of the Virginia-Carolina Chemical Corp., Mining Dept., Mt. Pleasant, Tenn. He will do consulting work and act as city recorder in Mt. Pleasant.

George W. Wunder has been appointed manager of the newly formed Nuclear Metals Div., National Lead Co. Prior to his appointment, Mr. Wunder was plant manager of the AEC's Feed Materials Production Center in Fernald, Ohio, which is run by National Lead Co.

Earl L. Bilheimer has been appointed resident manager, Meramec Mining Co., which was recently organized under joint ownership of St. Joseph Lead Co. and Bethlehem Steel Co. to develop and mine a deposit of magnetite and hematite near Sullivan, Mo. Mr. Bilheimer, who has been with St. Joe at Bonne Terre, Mo., since 1922, served most recently in operating supervisory capacities, leaves his post as manager of the employes' relations department to assume his new post. He will continue to maintain his headquarters at Bonne Terre until sometime this fall when offices are established for Meramec Mining at the plant site near Sullivan, Mo. The first shaft was started on September 1 and will be about 3000 ft deep.

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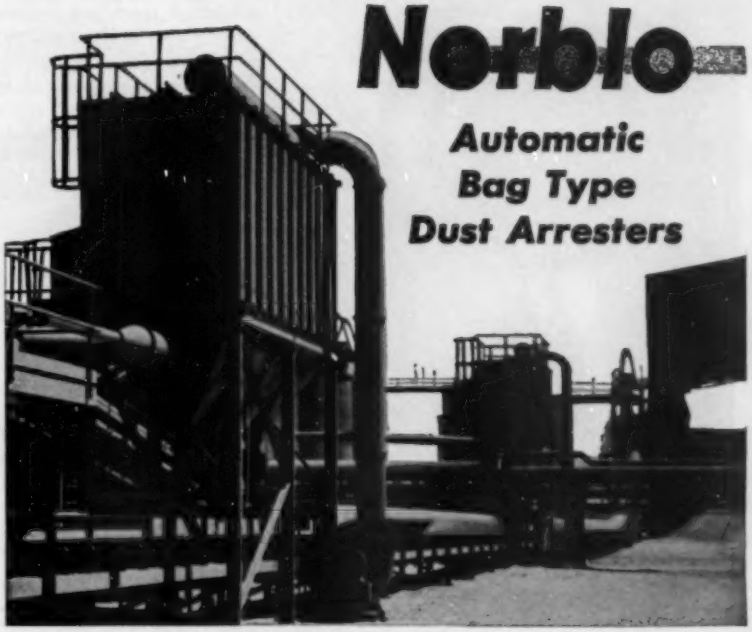

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Frank I. Konanowski has been named application engineer in the pyro-processing section of Allis-Chalmers processing machinery department, Milwaukee.

Paul Weir, chairman of the board of Paul Weir Co. Inc., Chicago, a consulting engineering organization, has been elected to honorary membership in England's Institution of Mining Engineers.

P. WEIR

William H. Martin has been elected president of Clevite Ltd.

Harold A. Waite, formerly from Whittier, Calif., now resides at Dover, N. J., and will be associated with the Mining Div. of Shahmoon Industries.

Alonzo M. Wells is now with the La Mina Ocujal, Nickel Processing Corp., Nicaro, Oriente, Cuba.

Edward L. Healy, Falconbridge Nickel Mines Ltd., Canada, has been transferred from the Sudbury District operations to the company's head office in Toronto.

C. DeWitt Smith has been elected vice president in charge of mining operations for Copper Range Co., Boston. Mr. Smith was recently appointed assistant vice president at St. Joseph Lead Co., New York.

Stewart St. Clair, consultant geologist, formerly a resident of New York, is moving to Florida and will build a home on Crescent Lake. Mr. St. Clair, who will be semi-retired, can be reached at Paradise Shores, Lake Como P.O., Fla.

Helmo M. Rand, previously of New York, is now working for the Indiana Geological Survey, and is residing in Bloomington, Ind. He begins graduate study at Indiana University this fall.

Robert J. Kupsch, formerly with the Neptune Gold Mining Co. in Nicaragua, is now associated with American Smelting and Refining Co., Engineering Office, Wallace, Idaho.

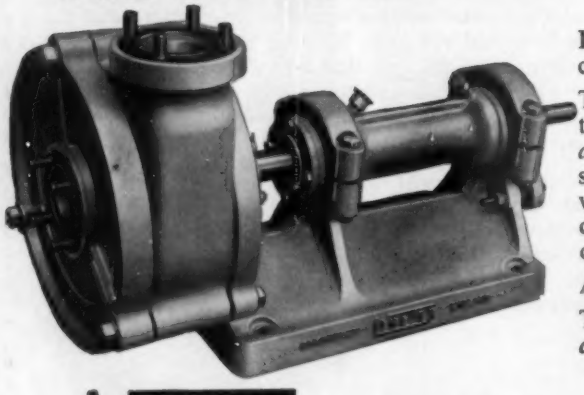
William Coleman, president of Banner Metals Inc., Cleveland, has been named a member of the board of directors of Pressed Metals of America Inc., Port Huron, Mich.

C. L. THORNBURG

The College of Mines, University of Utah, awarded a professional degree to **C. L. Thornburg** at the school's commencement ceremonies on June 10. The awards are made to former graduates who have distinguished themselves in their fields. Mr. Thornburg is mines geologist, U. S. Smelting, Refining and Mining Co.

John N. Butler, Jr., is employed as mine engineer at the Page Mine of American Smelting and Refining Co.

"Acettaremos una Gruesa"



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near Kellogg. He now resides in Kingston, Idaho.

W. B. Foster, former mine superintendent for American Chrome, has joined Pend Oreille Mines and Metals Co., Metaline Falls, Wash., as assistant superintendent.

Benjamin S. Dalton, formerly with the Kaiser Aluminum & Chemical Corp., Oakland, Calif., has been transferred to the Gramercy, La., branch of the company.

John T. Cullom, previously with the American Smelting and Refining Co., is now associated with the San Manuel Copper Corp., San Manuel, Ariz.

Bernard J. Fuller, formerly associated with National Lead Co. Inc., Monticello, Utah, is now holding the position of chief laboratory analyst for Western Nuclear Inc., Home on the Range, Wyo.

C. WENNER

Conrad Wenner has been appointed to the sales staff of Goodman Manufacturing Co., Chicago, as has **Harold Nordness.**

J. P. COURTRIGHT

John P. Courtright has been appointed as a consultant on metal mining, quarring, strip mining, and construction problems for Joy Manufacturing Co., Pittsburgh.

Thomas G. Murdock, since 1948 American Consul and Regional Min-

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erals Officer for the U. S. State Dept. in Elizabethville, Belgian Congo, has been visiting in the U. S. He left for Ankara, Turkey, on July 30, to take up his new post as First Secretary and Regional Minerals Officer at the U. S. Embassy. **Joseph C. Arundale,** succeeds Mr. Murdock in Elizabethville. He was formerly assistant chief in the branch of construction and chemical materials, USBM, Washington, D. C., before his appointment to the Foreign Service.

C. BARDWELL

International Smelting & Refining Co., subsidiary of The Anaconda Co., Tooele, Utah, has announced the following personnel changes: **Carlos Bardwell** has retired as manager of Tooele smelter operations and will be succeeded by **William J. McKenna,** formerly general superintendent. **Emile A. Steinbach,** assistant general superintendent of operations, has become general superintendent of Tooele smelter operations.

Elmer C. Speers has been promoted to design engineer, Kennecott Copper Corp., in the engineering department of the western mining division. He had been general mill foreman with the Utah Copper Div.

R. L. Brittain, formerly with Combined Metals Reduction Co., Pioche, Nev., has joined American Zinc Co. of Tennessee, Mascot, Tenn.

John Naylor, formerly of Lima, Peru, is now assistant resident engineer for the R. J. Tipton Associated Engineers Inc., Quito, Ecuador, for construction of a hydroelectric plant for the city of Quito.

J. R. Sampat, previously with the Cerro de Pasco Corp., La Oroya, Peru, has been transferred to Cerro de Pasco, Peru, as general foreman of the pilot plant. He had been ore dressing technician at La Oroya.

D. S. Lawrie has been appointed assistant mining engineer, Pahang Consolidated Co. Ltd., Sungei Lembing, Pahang, Malaya.

W. J. McKENNA

E. A. STEINBACH

The Lake Superior Iron Ore Assn. has changed its name to the American Iron Ore Assn., in recognition of the shift in the last decades of the sources of iron ore. Ore sources, now spread over the U. S. and Canada, were once mostly confined to the Lake Superior district. At the June annual meeting of the group, when the name change was announced, the following officers were elected: **H. C. Jackson,** Pickands Mather & Co., chairman of the board; **F. G. Pardee,** association staff, president; **H. S. Taylor,** Oglebay, Norton & Co., vice president; **W. A. Sterling,** Cleveland-Cliffs Iron Co., vice president; **H. E. Johnson,** association staff, vice president; **A. B. Rathbone,** Oglebay, Norton & Co., treasurer; and **G. E. Guthery,** Oglebay, Norton & Co., assistant treasurer. Newly elected members of the board of directors were: **A. L. Fairley, Jr.,** Shenango Furnace Co.; **G. W. Humphrey; W. S. Moore,** W. S. Moore Co.; **E. H. Winning,** Republic Steel Co.; and **R. T. Elstad,** Oliver Iron Mining Div., U. S. Steel Corp. Reelected directors were: **R. S. Archibald,** North Range Mining Co.; **P. D. Block, Jr.,** Inland Steel Co.; and **Carl C. Henning,** Jones & Laughlin Steel Corp. Guest speaker at the annual meeting was **Howard Turner,** director of research at J&L.

Charles Will Wright has completed a job for the U. S. Bureau of Mines, started two years ago before an auto accident in which he was involved. The project, entitled *What the American Mine Investor wants to know about Latin American Republics,* consists of 12 reports and includes tables showing U. S. dependency on foreign sources of mineral supply in the Western and Eastern Hemispheres. It will be published by the USBM as an information circular. Mr. Wright has spent the summer in Plainfield, Mass.

James P. Margeson, a director and executive vice president of International Minerals & Chemical Corp., Chicago, has retired after 17 years of service, in accordance with the company's retirement program. He will also resign from the board of directors.

Adam K. Stricker, Jr., is starting his own business in New York as a professional engineer and management consultant.

F. G. van der Hoeven, formerly associated with Unkra Mining, Seoul, Korea, has returned to his native country and resides at Hilversum, Netherlands.

Haydn H. Murray, previously associated with the Dept. of Geology at the University of Indiana, is now working in the Research Div., Georgia Kaolin Co., Elizabeth, N. J.

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Albert Feucht has been named manager of the Cleveland plant of the Le Roi Div., Westinghouse Air Brake Co., Milwaukee.

A. FEUCHT

Benjamin N. Webber, previously with M. A. Hanna Co., Iron River, Mich., is now associated with Mineracao Hanna do Brasil Ltda., Sao Paulo, Brazil.

Richard Quirk, formerly with National Lead Co., has left to join the Glidden Co. as manager of their Mining Div., Baltimore.

James G. Henderson has been transferred to Grand Junction, Colo., after completing an assignment in Spain for the U. S. Atomic Energy Commission.

Harry R. Karcher has joined the engineering staff of the Bituminous Coal Institute, and has taken charge of the new district field office at Portland, Me.

J. W. Thomas, previously residing in Juarez, Mexico, is now with Geophysical Service Inc., Dallas.

E. F. COOK

Earl F. Cook has been appointed dean of the University of Idaho, College of Mines, and Director of the Idaho Bureau of Mines and Geology.

Correction on Ewald Kipp

This picture of Ewald Kipp appeared in the August issue on p. 920, and was incorrectly identified as E. M. Kipp, accompanying an item about E. M. Kipp. Ewald Kipp has been with The Eimco Corp., Salt Lake City, for the past 12 years and wishes to assure his host of friends and acquaintances that he looks forward to many more years as one of the 1800-strong Eimco family.

EWALD KIPP

E. A. Eckhardt, geophysicist, has been appointed assistant director of the National Science Foundation for the Div. of Mathematics, Physical and Engineering Sciences. He had been associate director of research at Gulf Oil Corp. Dr. Eckhardt has been one of the world's pioneers in geophysical prospecting for petroleum. Born in Cedarburg, Wis., in 1888, he received his advanced education at the University of Göttingen, Germany, and the University of Pennsylvania where he also held the post of assistant professor of physics for four years. In 1917, he joined the staff of the National Bureau of Standards. Among his many contributions to NBS was his development of the first radio-acoustic ranging equipment for the U. S. Coast and Geodetic Survey, a system which, although greatly improved in detail, remains basically the same today. Dr. Eckhardt contributed to the development of several significant war devices through military research at the Bureau of Standards during World War I and for the National Defense Research Committee during World War II. The Soc. of Exploration Geophysicists, the American Geophysical Union, the American Geological Inst., and CIM are among the many societies in which he has taken an active part.

OBITUARIES

Haarlem E. West (Legion of Honor Member 1900) died at Santa Barbara, Calif., on Jan. 9, 1957. A native of England where he was born in 1869, Mr. West attended the Royal School of Mines, London, graduating in 1899. His mining activities took him throughout the world. He was general manager, Pacific Northwest Mining Co. Ltd. in Libby, Mont.; worked for Rio Tinto Copper Mines in Spain; Relief Gold Mines, Canada; and was located for some time in Nicaragua and Mexico.

Allan E. Craig (Member 1943) died on Apr. 7, 1957, following a short illness. A native of Denver, he graduated in 1914 from the Colorado School of Mines. For six years he was mill foreman for the Timber Butte Milling Co., Butte, Mont. During Mr. Craig's 35 years with the Mine & Smelter Supply Co., Denver, he achieved the position of chief service engineer and assistant manager of the Marcy Mill Div.

James S. Hazen (Member 1920) died on Feb. 20, 1957, in Tarboro, N. C., at the age of 68. Born in Hamilton, Ill., he attended Colorado College. Mr. Hazen's career took him to Venezuela, Chile, Trinidad, Mexico, Columbia, and to many states in the west. He had been superintendent at Walker Mining Co. and was also associated with United Verde Copper Co., Sullivan Machinery Co., Surface Combustion Co., Ranney Oil Mining Co., and Yaqui Gold Exploration Co.

Otto Haentjens (Member 1943) died on Mar. 31, 1957, at his home in Hazleton, Pa. He was president of Barrett Haentjens & Co., in Hazleton, and was known internationally as a designer of mine pumps. Born in Germany on Oct. 24, 1879, he obtained his engineering education at The Techniche Hochschule at Charlottenburg, Germany. Mr. Haentjens worked in Germany and Sweden in 1905 before coming to the U. S. where he secured engineering design work in New York, Oil City, Pa., and Buffalo. He founded the company he headed in 1916. Mr. Haentjens was a member of ASME and AIEE.

Frank H. Reed (Member 1932) died on Apr. 27, 1957, at the age of 67. A native of Logansport, Ind., Dr. Reed received a B.A. degree from Wabash College and a doctorate from the University of Chicago. He was chief chemist of the Illinois State Geological Survey, Urbana, a post he had held since 1931. During and following World War II he was consultant to several government agencies on the use of coal, and was sent on missions to Germany and Japan to study coking processes. Dr. Reed had held offices and served on committees of AIME, Amer. Chemical Soc., ASTM, and the Illinois State Academy of Science.

Harold M. Holkestad (Member 1946) died Apr. 23, 1957. Born in Mandan, N. D., in 1897, he came to Denver as a youth and was graduated from the Colorado School of Mines in 1924. At the time of his death he served as manager, mining supply sales, Colorado Fuel & Iron Corp., Denver. He came to CF&I in 1944 as sales engineer after working as a mining engineer in Utah, Montana, and California. His career included jobs as mine superintendent, mine foreman, and branch manager with various mining companies, leading to his specialization in ore grinding problems and steelmaking at CF&I.

Tony Skubic (Member 1956) died in February 1957. Born in Mount Iron,

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405 Miners Bank Bldg. Joplin, Mo.
Tel. MAyfair 3-7161

RAPHAEL G. KAZMANN
Consulting Ground-Water Engineer
Stuttgart, Arkansas

Continued on Page 1034

Minn., on June 18, 1908, he was owner of the Skubic Brothers Co. in Virginia, Minn.

George H. Wyman (Member 1944) died recently. A native of Ventura, Calif., he was born on June 4, 1884, and attended the University of Idaho. After graduating with a degree in mining engineering in 1907, he was engaged in flotation research and metallurgy for Hercules Mining Co. From 1923 to 1934 he was active in a cyanide operation and held various positions in Randsburg, Calif., including that of president and manager of Randsburg Aster Gold Co. In Mojave, Calif., he was engineer and part owner of the Cactus Queen Mine and later operated and held part ownership in Ruth Mine and Davenport Mine. In 1942 he joined the faculty of the University of Southern California as instructor of extractive metallurgy and lecturer in general engineering.

Necrology

Date Elected	Name	Date of Death
1950	Worth B. Andrews	June 26, 1957
1933	Byron B. Boatright	Unknown
1948	Harold V. Flagg	May 28, 1957
1905	George H. Garrey	July 23, 1957
	Legion of Honor	
1920	George C. Gerner	July 17, 1957
1942	Kershaw Harms	July 12, 1957
1937	Stacy H. Hill	July 7, 1957
1919	John E. Jones	July 1, 1957
1945	L. Russell Kelce	June 30, 1957
1948	Walter C. Kerrigan	July 16, 1957
1920	D. Ford McCormick	July 14, 1957
1917	E. S. McCurdy	July 13, 1957
1930	Conrad F. Nagel, Jr.	July 5, 1957
1936	Oliver J. Neslage	June 19, 1957
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1954	I. H. Wynne	July 11, 1957

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Coming Events

Sept. 8-Oct. 9, Commonwealth Mining and Metallurgical Congress, British Columbia to Nova Scotia, Canada.

Sept. 9-12, American Mining Congress, annual convention, Utah and Newhouse Hotels, Salt Lake City.

Sept. 13, AIME St. Louis Section, joint meeting with Amer. Chemical Soc. St. Louis Section. Hotel York, St. Louis.

Sept. 18-21, International Mineral Dressing Congress, Royal Inst. of Technology, Stockholm, Sweden.

Sept. 19, AIME Utah Section, *The Story of Mining and Milling at the Calera Mining Co., Cobalt, Idaho,* by E. B. Douglas, manager of the company, Newhouse Hotel, Salt Lake City.

Sept. 28, AIME Colorado MBD Subsection, Glenwood Springs, Colo.

Sept. 28, AIME Adirondack Section, visit to Barton Mines Corp., North Creek, N. Y.

Oct. 3-5, Seventh Annual Exploration Drilling Symposium, University of Minnesota, Center for Continuation Study, Minneapolis.

Oct. 6-9, AIME Society of Petroleum Engineers, fall meeting, Adolphus, Baker, and Statler-Hilton Hotels, Dallas.

Oct. 10-11, ASME-AIME Coal Div., Joint Solid Fuels Conference, Chateau Frontenac, Quebec.

Oct. 11, AIME St. Louis Section, fall field trip to Illinois-Kentucky Fluorspar District.

Oct. 15-19, AIME, Society of Mining Engineers Annual Meeting and Southeastern States Mining Conference, Hillsboro and Tampa Terrace Hotels, Tampa, Fla.

Oct. 17, AIME Utah Section. Speaker: Robert C. Mayer; subject: *Furnace Practices and Material Handling at Geneva Steel Co.*

Oct. 24-25, ECPD-EJC, general assembly, Hotel Statler, New York.

Oct. 30-Nov. 1, AIME Rocky Mountain Minerals Conference, Denver.

Nov. 8-9, AIME Central Appalachian Section, West Virginia Mining Inst., joint meeting, Greenbrier Hotel, White Sulphur Springs, W. Va.

Nov. 11-14, Society of Exploration Geophysicists, 27th annual meeting, Statler-Hilton Hotel, Dallas.

Feb. 16-20, 1958, AIME Annual Meeting, Hotels Statler and Sheraton-McAlpin, New York.

Apr. 17-19, AIME Pacific Northwest Regional Conference, Spokane.

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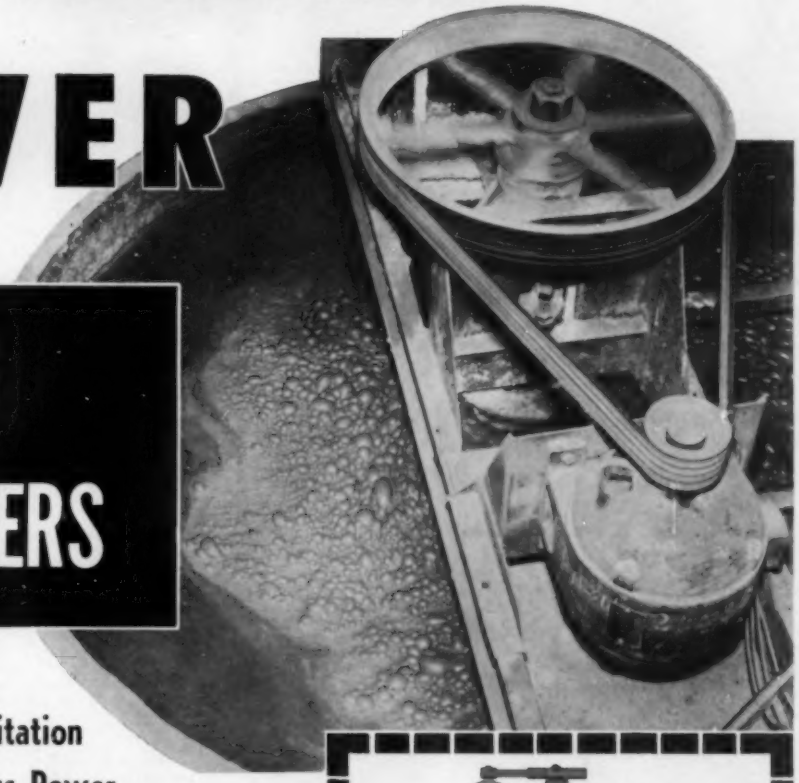

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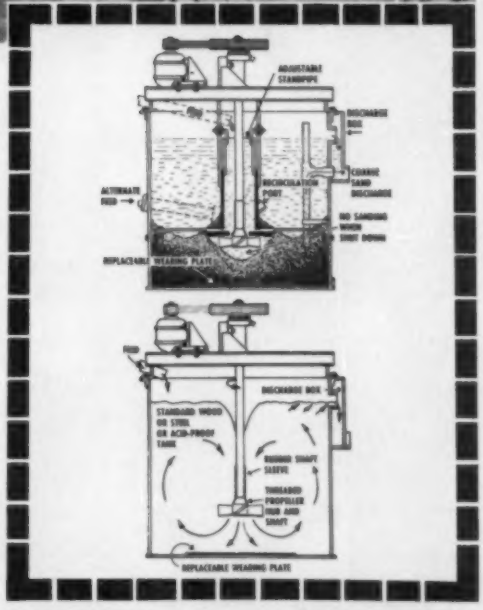

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